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OF THE

CENTRAL STATES VHF SOCIETY

KERRVILLE, TEXAS

1992

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First Edition

Welcome to the beautiful Texas Hill Country and the 26th annual Central States VHF Conference. We hope that you will enjoy your stay in the Kerrville area. The Conference Committee has been working very hard to assure that this year's gathering is in the fine tradition of Central States VHF Conferences.

Once again, thanks to ARRL for publishing these proceedings.

Among those helping me in putting together this year's Conference:

Program Chairman	Derwin King W5LUU
Prize Chairman	Gary Gerber KB0HH
Family Activities	Mattie Tynan & Katharine King
Registration	Rose Stahlnecker N5SRI & other members of the Hill Country Amateur Radio Club
Transportation	Bob Carpenter W3OTC
Facilities	Pat Rose W5OZI
Noise Figure Equipment	Derwin King W5LUU
Antenna Range	Kent Britain WA5VJB & Mark Thorson WB0TEM
Chairman Worldwide VHF Propagation Symposium	Dave Batcho N5JHV

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Bill Tynan W3XO	Pete Beedlow NN9K
San Hutson K5YY	Gary Gerber KB0HH

This year's Conference honors the memory of, and the many contributions made by, one of the Society's founders - Larry Nichols W5UGO.

73,

Bill

Bill Tynan W3XO

CENTRAL STATES
VHF
SOCIETY

26th Annual Conference
Kerrville, TX
July 16 - 19, 1992

Thursday July 16

1500 - 1700 & 1930 - 2100	Registration	
1500 - ?	Informal get-togethers, dinner etc.	
1500 - 1630	Tour of Mooney Aircraft	
1930 - 2100	Joint Meeting with Hill Country Computer Club Bob McGwier N4HY will speak on Digital Signal Processing	

Friday July 17

0730 - 1700	Registration	
0800 - 0820	Opening Remarks	Bill Tynan W3XO Derwin King W5LUU
0830 - 1200	Antenna Measurements	
0900 - 1200	**First Worldwide VHF Ionospheric Propagation Symposium** **Session 1 (* Indicates talks in this series)**	
0900 - 0915*	Opening Remarks	Dave Batcho N5JHV
0915 - 1000*	A Worldwide System of Smart 6 Meter Beacons	Bob Cooper K6EDX VP5D/ZL4AAA
1000 - 1030	Break	
1030 - 1115*	Solar Influences on VHF Ionospheric Propagation	Norman Cohen Space Environmental Services Center
1115 - 1200*	Profile Structure of the E Layer (Paper will be read by Mr. Cohen)	Frank Stewart Propagation Modeling and Applications Group NTIA
1200 - 1300	Lunch	
1300 - 1400*	Correlating Sun Noise Measurements to Solar Activity Data	Paul Wilson W4HHK & Paul Schuck N6TX
1400 - 1700	**Microwave Session**	Kent Britain WA5VJB Moderator
1400 - 1515	Microwaves Made Simple	Al Ward WB5LUA & Kent Britain WA5VJB
1515 - 1530	Break	
1530 - 1615	No-tune Construction Tips	Bill Olson W3HQT
1615 - 1700	Lightwave Communication	David Chase KY7B & Terry Wilkinson WA7LYI
1730 - 1815	Margarita Party	Hosted by YO Hilton
1815 - 1915	Dinner	(On your own)
1930	Leave for Point Theater	
1930 - ?	Swapfest and Noise Figure Measurements	

Saturday July 18

	Propagation Session	Joe Lynch N6CL Moderator
0800 -0830	Using TV Carriers for Propagation Monitoring	Al Ward WB5LUA
0830 - 0900	Exploiting Aircraft Scatter	Kent Britain WA5VJB
0900 - 0930	Multiple Power Level Beacon System	Dave Meier N4MW
0930 - 1000	The Case of the Invisible Meteor Shower	Joe Lynch N6CL
1000 - 1030	Break	
1030 - 1200	**Space Communications Session**	Bob McGwier N4HY Moderator
1030 - 1100	Overview of the Design of the Phase 3D Satellite	Bob McGwier N4HY
1100 - 1130	Low Down Antennas for High Flying Satellites (Patch Antenna Designs for Phase 3D)	Dick Jansson WD4FAB
1130 - 1200	Using GPS Satellites for Satellite Attitude Determination and Various Applications in the Ham Station	Tom Clark W3IWI
1200 - 1300	Lunch	
1300 - 1500	**EME Session**	Derwin King W5LUU Moderator
1300 - 1330	EME Overview and Update	Derwin King W5LUU
1330 - 1415	Various EME Topics	Hank Kasper K2GAL
1415 - 1430	Break	
1430 - 1500	"QRP" EME	Ray Soifer W2RS
1500 - 1600	VHF Forum	VUAC members etc.
1600 - 1700	Central States VHF Society Membership Mtg.	
1800 - 1900	Attitude Adjustment	
1900 - ?	Banquet Guest Speaker and Prizes	

Sunday July 19

0730 - 0900	SMIRK Breakfast	
0830 - ?	Informal gatherings bring slides tapes etc.	
0900 - 1200	**Worldwide VHF Ionospheric Propagation Symposium Session 2**	
0900 - 0930*	30 Years of Sporadic E Observations	Pat Dyer WA5IYX
0930 - 1000*	Trans-Atlantic Es Openings	Emil Pocock W3EP
1000 - 1030*	An Overview of 50 MHz Propagation Modes and Conditions	Steve Wagner W7CI
1030 - 1045	Break	
1045 - 1145*	50 MHz Propagation During Cycle 22	Panel Discussion Featuring Well Known Visitors from Various Parts of the World
1145 - 1200*	Closing remarks	Dave Batcho N5JHV & Bill Tynan W3XO
1400 - 1700	Texas Bar-B-Que prepared by Pat Rose W5OZI at QTH of W3XO Tierra Linda Ranch (Maps will be provided.)	

CHAMBERS AWARD RECIPIENTS

The John T. Chambers Award was instituted in 1970 on the suggestion of Bill Smith K0CER. The Award honors John Chambers W6NLZ for his many contributions to VHF, most notably his work with KH6UK proving the existence of the West Coast to Hawaii duct.

1971 Mel Wilson W2BOC for his dedicated observation and brilliant reporting of VHF propagation phenomena.

1972 Ed Tilton W1HDQ for his many years of research and reporting as Editor of QST's World above 50 Mcs.

1973 Tommy Thomas W2UK/KH6UK for his numerous VHF exploits particularly on the Hawaii to West Coast duct with W6NLZ. (It should be noted that he, in company with W4HHK, also showed the value of meteor scatter for working long distances on 2 meters.)

1974 Dick Knadle K2RIW for his design of amplifiers and Yagis parabolic dishes.

1975 John Fox W0LER for his studies of OSCAR telemetry.

1976 Joe Reisert W1JR for his many technical contributions to VHF and UHF and his oft demonstrated helpfulness to his fellow amateurs.

1977 Bob Sutherland W6PO for his dedicated efforts in bringing EME technical information to amateurs worldwide through distribution of the famous Eimac EME Notes.

1978 Wayne Overbeck N6NB for his technical accomplishments, in particular the design of the Quagi antenna, and contest activities.

1979 No Award presented.

1980 Jan King W3GEY for his work in amateur satellites.

1981 Louis Anciaux WB6NMT (Now KG6UH) for his promotion and technical contributions to 220 MHz in our continuing efforts to retain this valuable allocation.

1982 Al Katz K2UYH for his many technical accomplishments.

1983 No Award presented.

1984 Ron Dunbar W0PN for his technical contributions to the Amateur Satellite program in writing software and serving as a command station.

1985 Don Hilliard W0PW (ex W0EYE) for his technical contributions to VHF/UHF including the W0EYE Yagi.

1986 Paul Wilson W4HHK for his continuing technical contributions to UHF, especially in EME on 13 cm.

1987 Leroy May W5HN (ex W5AJG) for his over 50 years of contributions to VHF and UHF, including many articles in amateur magazines beginning in the 1930s.

1988 Al Ward WB5LUA for his many outstanding technical contributions in the field of VHF, UHF and microwave equipment.

1989 Kent Britain WA5VJB for his promotion of the microwave bands including his numerous articles on simple, easy-to-build equipment.

1990 No Award presented.

1991 Jim Vogler WA7CJO for his many outstanding technical contributions, including participation in first 10 GHz EME contact.

WILSON AWARD RECIPIENTS

The Wilson Award was instituted in 1982 in memory of long time Society member Melvin S. Wilson W2BOC. It is given for outstanding and continuing service to the Society or to VHF/UHF in general.

1982 Bill Tynan W3XO for his continuous service and dedication towards promoting VHF and UHF Amateur Radio activity.

1983 Ed Fitch W0OHU for 16 years of devoted service to the Society.

1984 Ray Nichols W5HFV for his many years of service to the society as it historian.

1985 Al Ward WB5LUA for many years as Prize Chairman and his numerous fine technical talks at various CSVHF conferences.

1986 Marc Thorson WB0TEM for his continued and valuable service to the Society.

1987 Jimmy Treybig W6JKV for his many DXpeditions to sometimes difficult spots to give us all new countries on 6 meters, as well as putting many rare countries on 2 meter EME.

1988 Lionel Edwards VE7BQH for his many hours spent conducting the 2 Meter EME Net on 20 Meters. In so doing, he has helped many new EMErs get started and many old time moonbouncers increase their stations worked totals.

1989 Joe Muscanere WA5HNK for his many years of service to the Society, including serving as it Treasurer for 10 years from 1979 to 1989.

1990 No Award presented.

1991 Kent Britain WA5VJB for his numerous contributions to the Society, especially running the antenna range at many Conferences.

CENTRAL STATES
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CORRELATING SUN NOISE MEASUREMENTS TO SOLAR ACTIVITY DATA

by

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Penn College of Technology
One College Avenue
Williamsport PA 17701

and Paul M. Wilson, W4HHK
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TN 38027

ABSTRACT

The received amplitude of solar radiation, a standard indicator of performance for sensitive microwave receiving stations, is known to exhibit significant temporal fluctuations as a function of solar activity. Statistical techniques have been employed to generate a predictive model, based upon observed 2304 MHz sun noise at W4HHK, and daily solar activity indices broadcast on WWV. Over a period of months, the model has proved accurate to within about one-half decibel. Future studies will attempt to generalize the model to other stations, and other frequencies.

SUN NOISE: FACT AND FALLACY

Microwave experimenters have long calibrated the performance of radiotelescopes, satellite tracking facilities and advanced Amateur Radio stations alike by measuring the intensity of microwave emissions received from our nearest stellar neighbor, the sun. It's amusing, at technical conferences across the country, to hear boastful comparisons of system performance: "My EME station gets fifteen dB of sun noise." "That's nothing; mine gets seventeen dB!" Or perhaps an experimenter will use sun noise measurements to justify a supposed design improvement: "I switched to Barry's feedhorn design, and my sun noise came up three quarters of a dB." In fact, unless the measurements were made at the same time, on the same day, at the same frequency, any conclusions drawn from such comparisons will be specious.

The sun, like all stars, is a powerful fusion reactor. It is also a powerful generator of broadband electromagnetic radiation, much of which we see as sunlight, some of which we hear in radio receivers as sun noise. The problem is, the sun is a poorly regulated signal generator, with daily and seasonal fluctuations in microwave radiation intensity of several dB the rule rather than the exception.

Fortunately, we need not be totally ignorant of these fluctuations. The National Institute of Standards and Technology (formerly National Bureau of Standards) broadcasts over its standard frequency and time stations (WWV and WWVH) three daily indicators of solar activity: 10.7 cm solar flux, "A" index, and "K" index. The exact meanings of these indices may be known to astrophysicists, but not to us! And although the literature con-

tains ample recent material dealing with the interpretation of WWV solar activity data [Atchison 1991, Healy 1991, Popcock and Blake 1991, Beehler and Lombardi 1991], we have adopted a more pragmatic approach to understanding solar noise: direct observation and statistical correlation.

STRUCTURING THE EXPERIMENT

The 2304 MHz station at W4HHK, which was involved in the first successful EME contact on that band in 1970, is depicted in Figure 1 below. It consists of a 0.41 F/D, 5.5 meter Kennedy parabolic reflector on an SCR-584 azimuth-elevation mount, which has been in continual operation since 1964. A circularly polarized 0.7 wavelength ID cylindrical waveguide feedhorn with choke ring yields a net antenna gain on the order of +39.5 dBic. An antenna-mounted GaAs FET preamplifier and low-loss feedline set the overall receiving system noise figure at 0.85 dB.

Since June of 1991, this station has been used to make daily measurements of sun noise by integrating audio noise in a 2.2 kHz receiver bandwidth, from a linear CW detector, with AGC disabled. The antenna was pointed alternately at the sun, and a "cold" point in the sky with an expected noise temperature of 25 Kelvins. The dB difference in received noise was then observed by averaging 7 to 10 readings on a digital rms voltmeter.

Several dozen such sun noise measurements were made, over a period of months so as to capture any seasonal variations in solar activity. Concurrent with each observation, the Ottawa 10.7 cm solar flux number, and mean geomagnetic field measurements (A and K indices) were recorded from WWV. It was hoped that these three solar activity indicators, as provided by the National Institute of Standards and Technology, would serve as useful predictors of observed sun noise.

FIGURE 1
W4HHK 2304 MHz station, 1991

STATISTICAL ANALYSIS

W4HHK noticed some time ago, and reported at the 25th Conference of the Central States VHF Society (July 1991, Cedar Rapids IA), a direct correlation between the WWV 10.7 cm solar flux number and his observed sun noise at 2.3 GHz. The WWV number is based upon sun noise received at local noon in Ottawa, Ontario, measured at a frequency of 2.8 GHz [Rosenthal and Hirman 1990]. Since the two frequencies of observation are reasonably close, the longitudes of the two observers are separated by less than one terrestrial time zone, and the W4HHK measurements were often made near midday, this correlation is not particularly surprising. As a first order approximation, W4HHK hypothesized for his station the following relationship between sun noise and the WWV solar flux number:

$$\text{Sun noise (dB)} = \sqrt{\text{(WWV Flux)}} + 1 \qquad \text{[Eq. 1]}$$

This approximation, appealing in its simplicity, appeared to hold reasonably well for sun noise measurements in the range of 15 to 16 dB, with errors increasing for higher and lower sun noise levels. Figure 2 is a scatter diagram of the predictions from this model, as compared to measured sun noise, for a sample of three weeks' daily observations. Note the concentration of data points above the regression line for low values of sun noise, and below it for higher sun noise values. Although a correlation coefficient of 0.916 was achieved, the obvious disparities between prediction and observation led us to believe that a better model could be built with additional independent variables (predictors), of which WWV gave us two candidates: A index and K index.

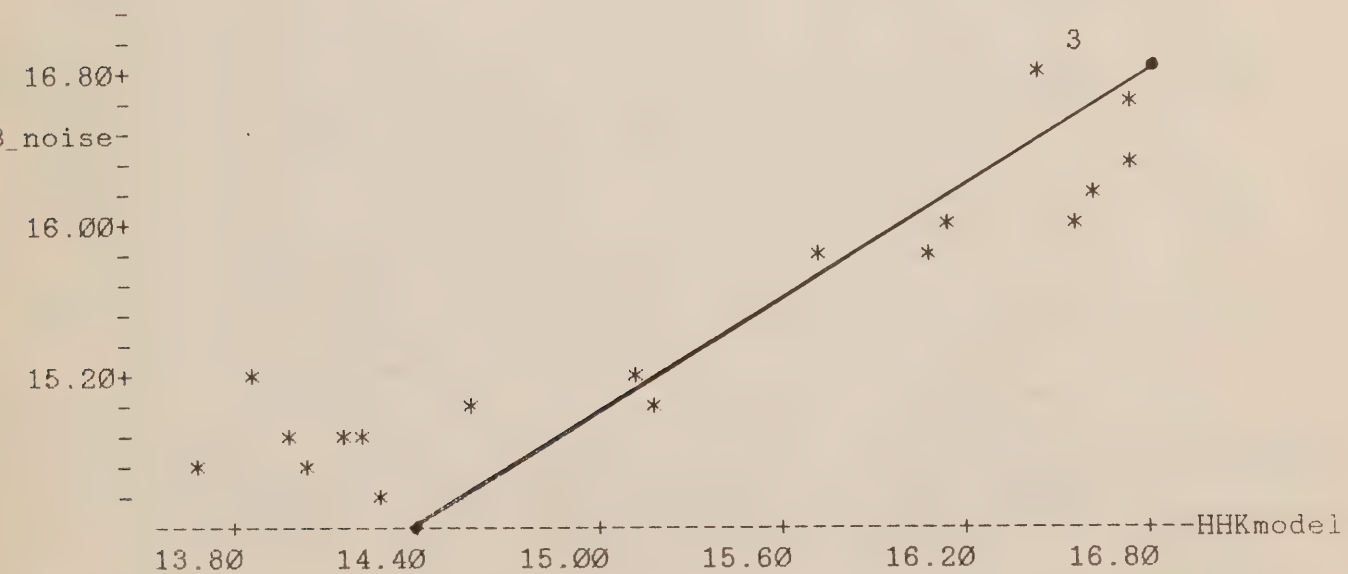


FIGURE 2
Scatter Diagram of Predicted vs. Observed Sun Noise, W4HHK Model

For this same preliminary sample, correlation was sought between the WWV solar flux index, A index and K index (predictors) and W4HHK's observed sun noise (the response variable). We expected the sun noise to follow the WWV flux index rather well, and it did, as seen in the scatter diagram of Figure 3(a). As Figure 3(b) indicates, the relationship between A index and sun noise is not nearly so strong. And Figure 3(c) shows almost no discernible correlation between sun noise and K index. Thus we conclude that K index is the weakest predictor of recovered sun noise, and exclude it from our further analysis.

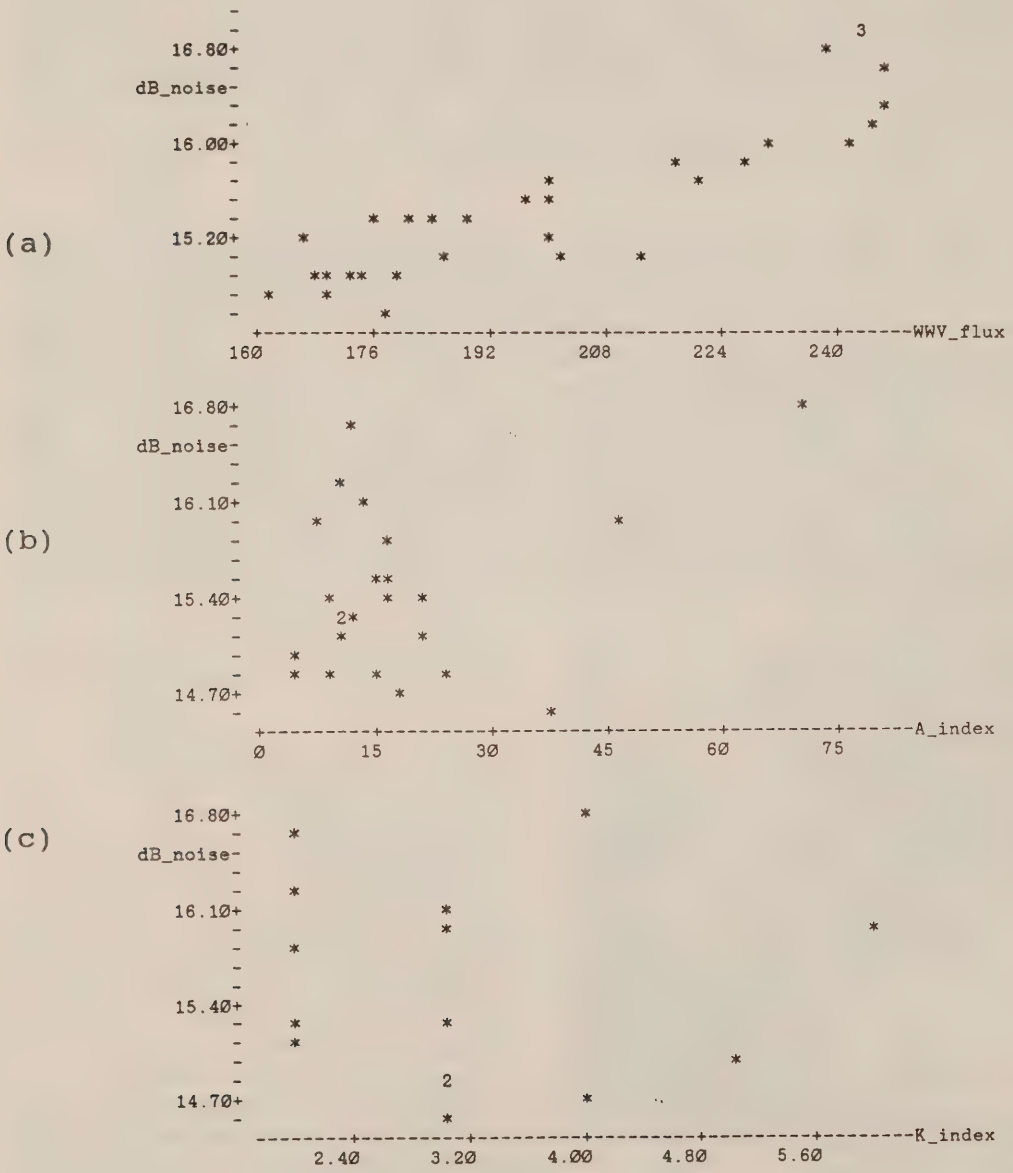


FIGURE 3
WWV Solar Flux Number (a), A Index (b), and K Index (c) as predictors of measured sun noise.

Turning his attention to WWV 2.8 GHz solar flux and A index, N6TX employed multiple linear regression analysis on a microcomputer, to come up with the following refined predictive model from W4HHK's preliminary sample:

Sun Noise (dB) = 11.3 + (WWV Flux/51) + (A Index/141) [Eq. 2]

Agreement between observed and predicted values of sun noise, employing Equation 2, yielded only a negligible improvement (to 0.920) in correlation coefficient over the initial model. However, the resulting scatter diagram (Figure 4) shows that data points fall noticeably closer to the regression line than they did initially.

Satisfied that we had a working strategy, we next sought to refine our predictions by amassing a much larger data base of observations covering several months, and exploring various possible transformations of the regression model. One which gave us acceptable agreement between observation and prediction was:

Sun Noise (dB) = 12 + (WWV Flux/59.5) + (A Index/97.1) [Eq. 3]

which you will recognize as merely a fine-tuning of Equation 2. Although further improvement in fit is doubtless possible, we submit this as our final model of the present study, and will explore its predictive validity below.

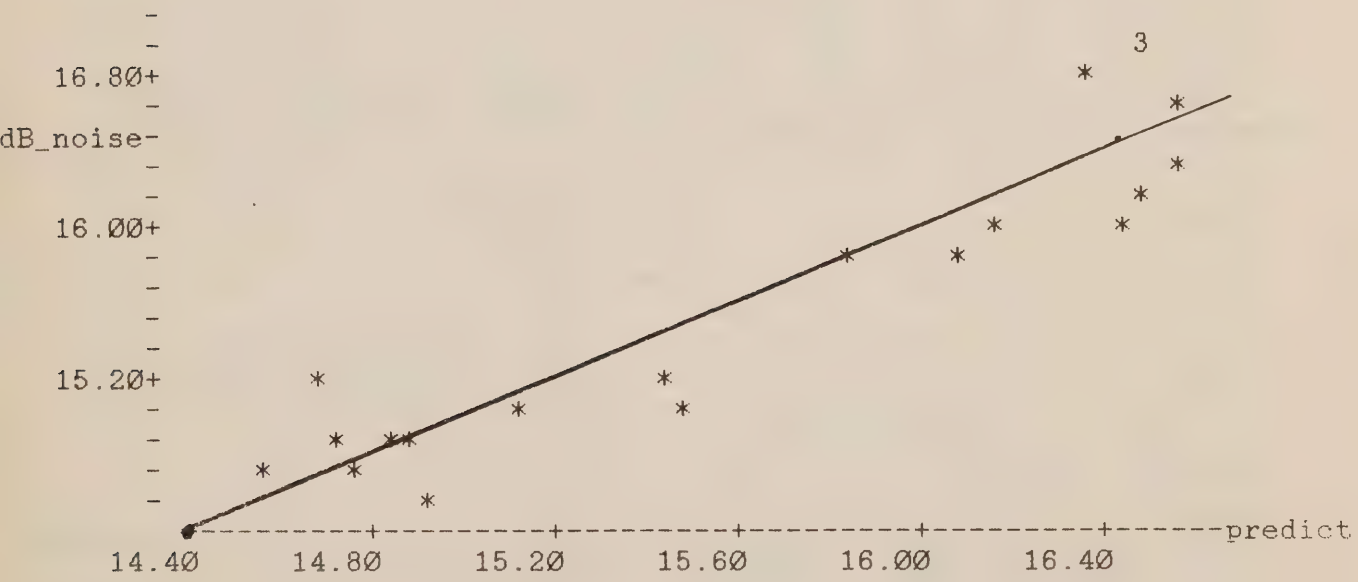


FIGURE 4
Scatter Diagram of Predicted vs. Observed Sun Noise, N6TX Model 1

TESTING THE PREDICTIVE MODEL

Prior to generating the final predictive model, a holdout sample was randomly drawn without replacement from the sun noise and solar activity data base. Statistical tests were performed to assure that this sample constituted an unbiased representation of the underlying population. The size of the sample was tested to assure that it would produce statistically significant results. The pertinent WWV data were applied to Equation 3 to generate sun noise predictions for the holdout sample, and these predicted values were compared to measured sun noise. They lined up well, as seen in Figure 5.

The resulting correlation coefficient of 0.927 represents a slight but noticeable improvement over Equation 2. It achieves significance well beyond the 0.05 level, which indicates excellent agreement between observation and prediction. Such discrepancies as we detected were random rather than systematic. That is, the correlation between the predictive errors and measured sun noise was insignificant (r = -0.37). More important, the differences between prediction and observation averaged 0.17 dB, and never exceeded 0.44 dB, suggesting that our predictions are limited only by the inherent accuracy with which we can measure sun noise. We suggest that Equation 3 accurately predicts sun noise for the 2.3 GHz station at W4HHK, and will discuss shortly a process for generalizing these results to other stations, and other frequencies.

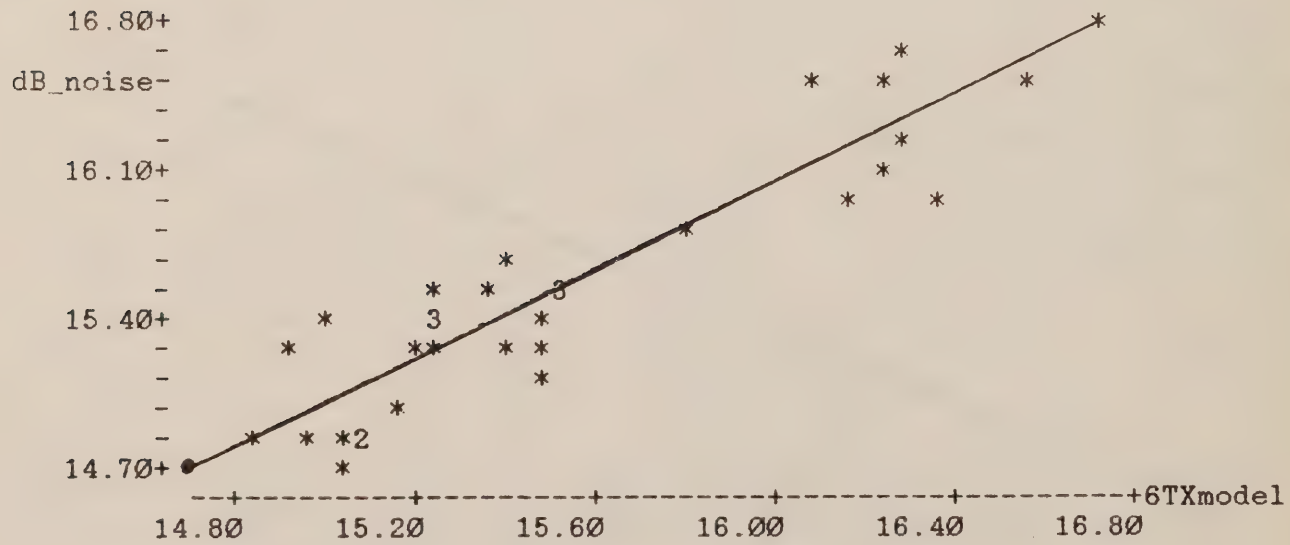


FIGURE 5
Scatter Diagram of Predicted vs. Observed Sun Noise, N6TX Model 2

AN EXPLANATORY HYPOTHESIS

The scientific method, as espoused at institutions of higher learning, requires that the investigator first formulate a hypothesis; then design experiments to test that hypothesis; next conduct those experiments to gather data; and finally perform statistical analysis to ascertain whether the data supports or rejects the hypothesis. We admit to having sidestepped established procedures somewhat, in that we first gathered data experimentally, then designed a statistical analysis procedure to sift through that data. We shall now totally subvert (and pervert) the scientific method, by utilizing that analysis to formulate a hypothesis!

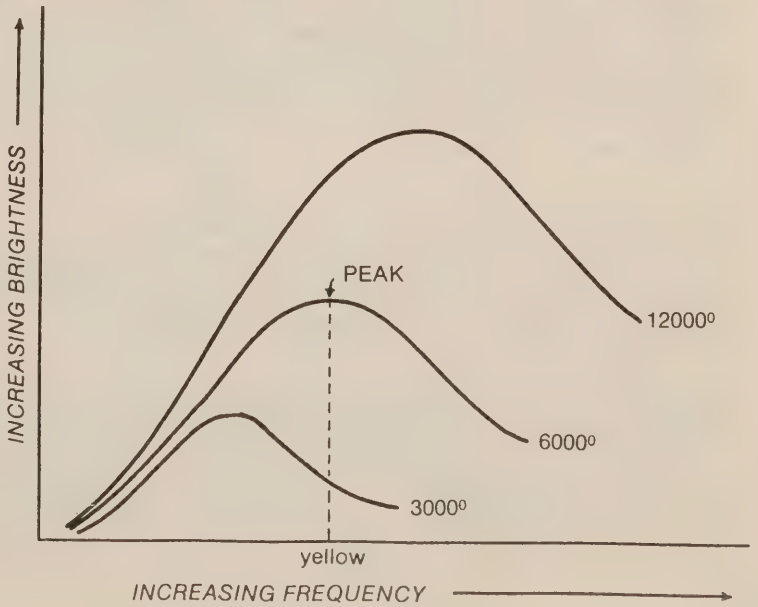
Some call this the needle-in-a-haystack approach to science: I don't know what I'm looking for, but I'm sure it's there somewhere. Our most powerful analytical tool is the inter-occular trauma test: when a relationship is so overwhelming that it hits me between the eyes, I'll know I've found something significant.

What hit us between the eyes here is that the sun is supposed to be a thermal "black-body", radiating differently at different frequencies, as determined by its 5800 K surface temperature (see Figure 6, from Jespersen and Fitz-Randolph, 1990.) But microwave radiation from the quiet, or undisturbed sun (Figure 7) seems to fit a Planck radiation curve for a significantly warmer black-body [data from Shaffer, 1990].

Perhaps our receivers are responding not to the sun's surface temperature at all, but rather to its somewhat warmer (20,000 K) chromosphere, or even its amazingly hot (100,000 K) corona. Since, for example, solar flares are known to extend well into the sun's upper atmosphere, one could well expect the effective temperature *around* the sun to vary with solar activity. The very activity which the WWV data captures, and our statistics analyze.

FIGURE 6

Heat signature varies with the temperature of the radiating body.



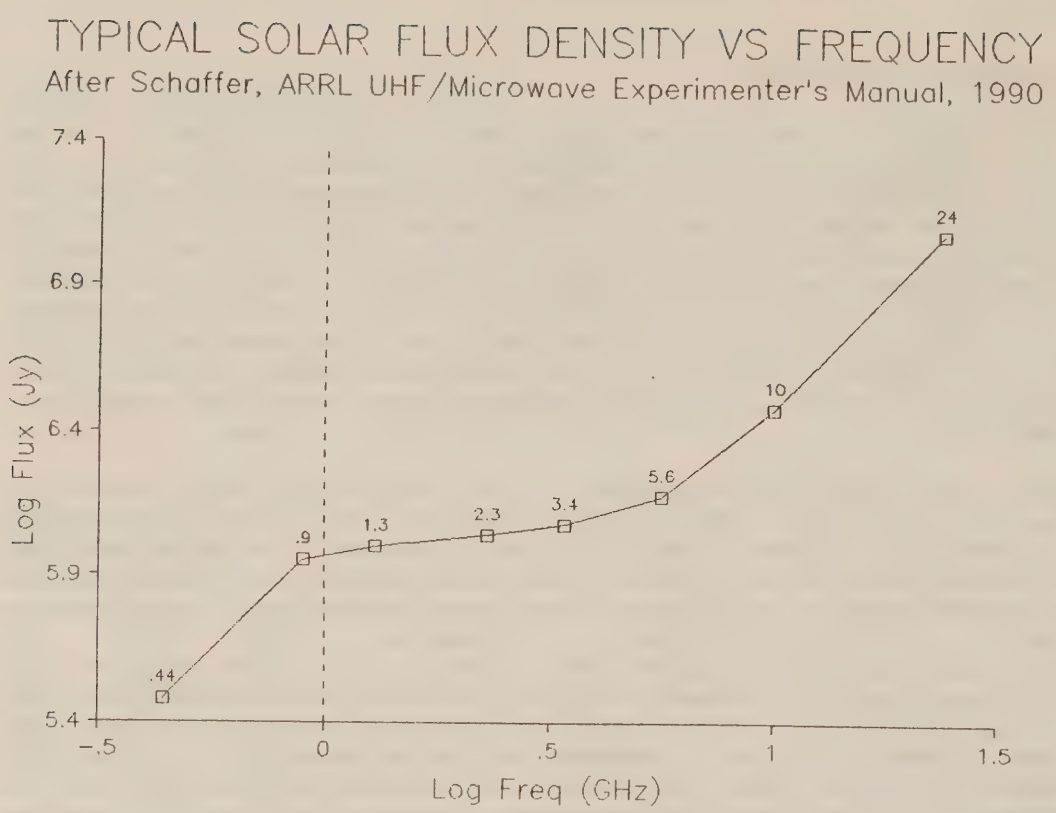


FIGURE 7

Microwave radiation from the sun seems to fit a far warmer blackbody curve than we had expected the sun's temperature to produce.

GENERALIZING THE RESULTS

Note in Figure 7 that, at least over the limited range encompassing the amateur 33 cm through 5 cm bands, solar flux appears relatively linear with frequency. (Figure 7 is a log-log plot, so the region between 0.9 and 5.6 GHz will still appear as roughly a straight line on a linear graph). Such a line may be described in terms of its slope and y-intercept. In our general predictive model, solar flux will relate to the intercept, and slope can be expected to be indicative of geomagnetic activity.

If we accept WWV Solar Flux number and A index as our predictors, and observed sun noise as our criterion measure, then an appropriate model for sun noise at a particular frequency, measured by a particular station, will be of the general form:

Sun Noise (dB) = α + β (Flux Number) + δ (A Index) **[Eq. 4]**

where α is a constant unique to the particular station (encompassing G/T and operating frequency), and β and δ weigh the contributions to measured sun noise of solar flux and geomagnetic activity, respectively. We have already estimated α, β and δ for the 2.3 GHz station an W4HHK. It now remains for us to determine such constants for other stations, at other frequencies.

IMPLICATIONS FOR FURTHER STUDY

Thus far, all of our computations have been based upon sun noise measurements taken by one station, at one frequency. However, a long term objective of our efforts is to generate a predictive model of sun noise for *any* observer, given pertinent station parameters and WWV solar activity indices. Toward this end, it will be necessary to accumulate a sizable database of sun noise observations, from numerous stations operating in the various microwave bands. We believe that from such a database, we can derive an equation which predicts sun noise for any station, given that station's antenna gain, overall noise temperature, frequency of operation, and the pertinent WWV solar activity data. The cooperation and assistance of the world's microwave radio amateurs is thus hereby solicited.

There are probably several hundred stations worldwide with EME, satellite, and radioastronomy capabilities in the 70, 33, 23, 13, 9, 5, 3 or 1 1/4 cm amateur radio bands. We are hoping a significant portion of these stations capable of observing sun noise can be enticed to participate in basic research. Those experimenters possessing such stations can make a significant contribution to knowledge by periodically measuring sun noise, along with the corresponding WWV A, K, and 10.7 cm flux index readings. We request that those desiring to participate in this research send logs of such readings monthly, along with as detailed a station description as they are able to supply. This information can be sent to N6TX at his byline address above.

If sufficient data is received, the statistical techniques outlined herein will be applied to the broader problem of developing a general sun noise model. The results will be published in both the amateur radio press and the scientific literature, and all participants gratefully acknowledged.

The present investigation is only a start. We look forward to including your data in this more ambitious study. If we hear from enough of you, you will most certainly here more from us. Thanks in advance for your contribution to the radio art and science.

CONCLUSIONS

The sun noise recovered by any sensitive microwave receiving system is of course a function of system performance, but it also varies with solar activity. Sun noise measurements are an effective method of quantifying system performance *only* if steps are taken to compensate for fluctuations in solar emission levels. A method has been presented for calibrating system performance against broadcast solar flux indices. Once the calibration function has been computed for a given station, sun noise measurements can be readily predicted from WWV data. Any disparity between predicted and observed sun noise measurement may then be attributed to actual variations in system performance.

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LASER COMMUNICATIONS

By David Chase KY7B and Terry Wilkinson WA7LYI

History :

The first Amateur LASER communications experiments were done in 1963. Twelve members of the amateur radio club from the Electro - Optical Systems company of California set up communications 118 miles across the southern California desert between two mountain tops. The equipment used consisted of a 4 foot long Helium Neon (HeNe) Laser that only put out 1/8 Milliwatt (mW). The receiver was a 12 inch telescope and an S20 photomultiplier tube. This contact was unfortunately a one way contact, and it was not recognized by some amateur groups for the OUTSTANDING achievement that it was for its day. The one man Mercury space flights were taking place.

The next set of amateur experiments were done by Steve Noll, WA6EJO. Steve set the distance record for LASER communication on 6/9/79 at 15 miles, which remained the distance record until 1988. Steve was using low power HeNe gas lasers. On June 8, 1991, Steve increased the distance record for HeNe lasers to its present 57.7 Miles.

The Bedlam Microwave Society began experimenting with LASER communications in 1987. The first contacts were made using a 15 mW Helium Cadmium (HeCad) laser with a photomultiplier tube and a large fresnel lens in the receiver. The initial experiments can best be described as a learning process. One way contacts were initially made at 5 miles and 15 miles for practice. Two way contacts were then made at 21 miles and 28 miles in early 1988.

On 6/12/88 the Bedlam Microwave Society set up communications over the 56 mile path between Mount Lemon and Mount Graham in Arizona. This was a new distance record for lasers.

On 8/7/88 the Bedlam Microwave Society established communications over the 95.6 mile path between Mount Lemon and South Mountain in Arizona. This was a new distance record for lasers.

On 6/9/91 the Bedlam Microwave Society established communications over the 154.9 mile path between Mount Lemon and Towers Mountain in Arizona. This is the current distance record for lasers. All contacts were done using the same 15 mW HeCad lasers, with progressive improvements to the design with each contact.

Bedlam Microwave Society :

The Bedlam Microwave Society began experimenting with medical surplus 15 mW HeCad lasers in 1987. These tests generally used a 2,100 foot mountain just south of Phoenix Arizona on one end of the contact. This mountain has large radio towers with red beacon lights which made this site easier to find for one end of the contact. The other end of these contacts were at various points in the desert near the I-10 freeway that heads south from Phoenix towards Tucson. This situation made it easy to exit the I-10 freeway a few more miles down the road as our equipment got better and the distances got progressively farther. Much of this area is unoccupied desert on or near an Indian reservation.

These initial contacts brought us needed experience, and allowed us to test newly constructed equipment and new procedures. They also brought us curious park rangers, drunk Indians, lonesome astronomers, Police officers checking out strange lights, and large numbers of curious onlookers.

Laser Equipment Used :

Our equipment consists of a pair of home built "transceivers". The receivers consist of large wooden rectangular box with an 18" almost square fresnel lense on the front. The lense focuses its 324 square inches of light on a very sensitive photomultiplier tube. The output from the photomultiplier tube then goes to an opamp and an audio filter. The audio filter is used to get rid of the 60 HZ buzz from all of the A.C. powered lights when operating anywhere around city lights. The gain of the photomultiplier is adjustable. The detected audio signal is then sent to a speaker or earphones. The transmitters consist of a 15 mW helium cadmium laser mounted on top of the receiver box. The laser mount has micrometer adjustments to .001 inch in both azimuth and elevation. The outgoing LASER beam is "chopper" modulated by passing through a small fan, and a solenoid is used to interrupt the beam and send CW. The beam is also passed through a a pair of lenses called a collimator, that effectively makes the beam smaller for a given distance. The collimator used is a X10, which makes the beam 1/10 the size of a non-collimated beam at the same distance.

Laser Contacts :

On 6/12/88 the Bedlam Microwave Society set up communications over the 56 mile path between Mount Lemon and Mount Graham in Arizona. This was the first real long distance test of all of the equipment with both ends of the laser shot being fully portable. Both mountain tops are over 9,500 feet in elevation, and the signals were extremely strong and stable. This was our first time for trying to locate one mountain top in the dark from another mountain top in the dark. The slope of the mountain on Mount Graham necessitated that to make the laser even close to level, a shelf was dug in the side of the mountain. Not only is digging in the dark at 10,700 foot elevation no fun, three separate shelves were dug before we were able to make contact. This contact was a new distance record for lasers.

On 8/7/88 at 0830 hr UTC a laser contact was completed at a distance of 95.6 miles between KY7B and WA7LYI. KY7B was located on South Mountain near Phoenix Arizona, and WA7LYI was located on Mount Lemon near Tucson Arizona. The contact was delayed for four hours while waiting for a severe thunderstorm to subside on Mount Lemon. After 15 minutes of scanning the laser across KY7B's location the beam was sighted. The beam was approximately 100 feet across at 95 miles. KY7B then scanned his laser across WA7LYI's observed location until the laser beam was observed and signals were peaked both ways. This sighting and alignment process took several hours. A contact was completed and signals were 20 DB out of the noise. This contact broke our own previous distance record.

On 6/8/91 right at sundown, Dave KY7B and Jim WA7CJO arrived on Mount Lemon and began setting up their laser equipment for a 150+ mile laser contact. Terry WA7LYI, Bruce N7PMO and Gary WB7SLY had set up their laser equipment one day prior and had been waiting. After all equipment was set up, we aimed our 1,000,000 candlepower spotlight, and 400 watts of incandescent lights towards Mount Lemon, and they could just barely see our lights in the darkness. After only 5 minutes of aiming we could see their laser pointed at us. The beam was much higher in the sky then we had expected, but almost exactly on in azimuth. This aiming process usually takes much longer, and it took several hours for the 95 mile LASER shot. We determined that their beam was about 250 feet across, which was wider than we had expected. We felt that the beam was being scattered by the atmosphere and all of the floating debris in it left over from a forest fire on Mount Lemon. The beam was also not nearly as strong as in our previous laser contacts, partially due to the distance involved.

We observed that the beam was fading completely in and out several times a second. The beam was visible with the naked eye, but just barely. We had the guys move the micrometers on their LASER back and forth in both azimuth and elevation, trying to peak up the signal and discovered several things. The micrometer adjustments to the beam were not nearly as critical as we thought they would be. Our micrometers read out in .001 of an inch, and on our 95 mile shot it took about 1/3 of a turn to sweep all the way across the other station. This time the beam was visible for almost two full turns of the micrometer. There was not really any peak where the beam was the strongest.

We then set up our LASER and after a few minutes of adjustments they could also see our LASER, just barely. After several minutes of LASER adjustment and discussions, conditions got worse and the LASERS were no longer visible with the naked eye. At this point the great sensitivity of the 18" square fresnel lense and the photomultiplier tube was fully appreciated. Our Receivers were still able to detect the modulated beam when it was there, even though it was not visible with the naked eye. Due to the rapid fading in and out the CW was impossible to copy. We waited for conditions to change and it didn't take long.

The wind picked up on Mount Lemon, and Dave and Jim were advised that there was a storm front moving in, with high winds and possible lightning. It is typical on these long distance laser shots to have to wait until 2 - 3 AM for the air turbulence to subside and the winds to die down. This time it didn't look like we were going to get the chance. Dave and I tried fast CW, very slow CW, and everything else we could think of, but the CW was just not readable with all the rapid fading. At times the air would be still momentarily, and the signal would actually get loud for about a second or so. Like it or not, we decided to wait an hour or more to see if conditions would improve, knowing that the guys on Mount Lemon might have to leave at any time.

As midnight local time approached, weather conditions slowly got worse. Over the next hour or so we watched the stars slowly disappear from the southern sky as the clouds moved in. The weather conditions on the Mount Lemon end amazingly did not get any worse. Unexpectedly, a wind appeared at our location from the North, and as we waited things started to clear off slowly. Finally, at about 2:30 AM local time, things had improved enough to attempt a contact. We had been attempting to send CW one way or the other every 30 minutes or so for the past 5 hours just to test conditions. Dave and I decided to attempt a moonbounce style contact (both sets of call letters, signal reports "o"s that full calls had been copied, and "r"'s that everything preceding had been copied). On went the earphones. Finally at 2:50 AM local time on 6/9/91, the contact was completed. Conditions had improved just enough to make it. According to several computer programs, the distance covered was 153.9 miles.

LASER COMMUNICATIONS PROBLEMS

Our experiments have shown that 90 % of the problems with amateur laser communications were connected with aiming the laser. Aiming a laser at a second station turned out to have two separate problems.

LOCATING THE OTHER STATION:

LESS THAN 50 MILES

The normal procedure for establishing initial contact is to determine as close as possible exactly where the other station is going to be, in both azimuth and in elevation. At the closer distances binoculars are all that is needed. Various other methods were tried to determine the exact location of the other station. Having one station on an easily identifiable mountain has always helped. If the other station is lower in elevation, and can move to a dark location, several methods can work. A small hand held spot light worked well for under 40 miles, as well as high powered photostrobe. Both of these methods worked well when one end of the contact was a "known" location, i.e. large mountain with red lights on top, and the second location was in an area without much light. Binoculars are also a big help. Five vehicle emergency flares in a pile were also tried, but were not easily visible. Anything that will make the location stand out from the rest of the surrounding lights will help in locating its position. It is felt that just prior to the sun setting, a mirror could be used to reflect light to the other station so show the location. A board containing four square feet of mirrors has made the trip with us several times, but it always seems to be jinxed. The other station is not in place before the sun goes down or the sun is covered with clouds. This method might work well for some other group without a curse.

OVER 50 MILES

Depending on distance and conditions in the air, the other station will be beyond visible range at some point. Our group uses topographical maps to determine the exact longitude and latitude for each of our locations. Several different computer programs will give the bearing and distance for each location. At 95 miles our 50,000 candle power search light was just barely visible with good binoculars, if you knew exactly where to look. At less than 50 miles having a transit or other survey device to determine the exact bearing becomes a **BIG** help. Beyond 100 miles it is mandatory. At 154 miles our second group was able to faintly see the 1,000,000 candlepower spot light through binoculars. No one was more surprised than us. This spotlight also gave us a visit from every moth in the county. It helps when both ends of the path are on mountain tops for several reasons. Having clear, still air at the higher elevations helps. When the station you are trying to contact is on a tall mountain, even from 100 miles away they will be several degrees higher in elevation than the surrounding lights.

AIMING THE LASER:

If possible, use a transit so you know exactly where to look, and a transit so you know where to point the spot light. If possible the transit should be behind and higher than the laser. This will allow the transit to actually look down the outgoing laser beam with a minimum of parallax error. The slight parallax error in elevation apparently makes little difference.

LASER MOUNTING

Our system started with several sizes and types of tripods, before going to the current method of mounting the entire system on two small sawhorses and using shims under the front or back for the rough alignment. A movement of 1/4 inch on the transmitting end will move the laser beam several miles on the other end 100 miles away. The importance of having a sturdy setup can not be overstated. Our setup uses a large rectangular box to house the receiver, with the fresnel lens mounted on one end. The laser itself mount directly on top of the receiver, and has micrometers for the fine azimuth and elevation adjustments. It becomes important to know where exactly where to aim, as the entire box is pointed and then shimmed so that it is level.

Our lasers were again measured for power just prior to the 154 mile laser shot, and we were surprized to learn that the power had dropped to 10 mW at some point in time. The loss of 1/3 of our original power did not appear to be a problem.

We are already making plans for our next shot, and hope to find something in the 200 mile or so range. We will be using air cooled Argon lasers during the next laser shot. Since our last shot we have been able to use a hi-tech computer program that plots out communications paths at microwave frequencies. The program uses longitude and latitude for input on both ends of the path. The program has a large database that contains geographical information about everywhere in Arizona (and several other states to the North), at least down to 1/2 square mile in detail. Unfortunately this database is 650 megabytes in size and comes on a CD ROM. The program "looks" at the path between while it calculates the elevation at both ends, and the elevation for a specified increment along the path. It also accounts for the curve of the earth, which starts to become real important over 100 miles. The program has been very successful at eliminating every path proposed so far, but it's better that finding out the path is no good the other way !

GETTING PERMISSION / BLINDING THE BATS :

We have always had good luck obtaining the needed permission to operate our lasers from the U. S. Forest Service, City Parks Departments, Observatory Administrators, and others. Communicating with them cleared up their concerns and answered any possible questions. Most people seem genuinely interested in our work. The Observatory officials on Mount Lemon were concerned about a statement made by the Forest Service. The Forest Service voiced concerns regarding other lasers operated at the observatory by the Jet Propulsion Laboratory. They were concerned about the possibility of blinding bats. We have always obtained written permission from the Forest Service to set up lasers on any mountain top that is in their jurisdiction. It is highly suggested that other experimenters do the same.

LASER SAFETY :

Experimentation with laser communications requires that one be familiar with the hazards of laser energy and the proper safety procedures required to prevent injury to oneself and others. First and foremost: NEVER, NEVER look directly into a laser beam, it would probably be the last thing you would ever see clearly, if at all. Remember the Cardinal Rule of not looking into a feed horn while transmitting; well, this would be at least as bad if not much worse.

Second : Always be aware of who may be near the operating laser, such as curious onlookers, stray Indians, etc. Assign one of your crew the sole duty of keeping track of anyone and everyone in the area, particularly small children and anyone that could potentially walk into the laser beam area. Preferably, all observers should be asked to stay behind the laser, including any fellow amateurs. The person operating the laser should be alert and ready to stop or block the beam, if necessary.

Third : Although small aircraft and commercial aircraft are not likely to be heading directly into the laser beam, (this would mean they are also headed straight for the mountain top !!) consideration must be given for the possibility. Your laser receiver is a very good indicator of aircraft in the general laser beam area. The aircraft strobe lights all aircraft have, make a very distinguishable and loud POP in the headphones or speaker. This has been noticed on aircraft many miles away, which were observable only in binoculars. The aircraft were very observable to the receiver. It is recommended that the beam be blocked when there are any aircraft in the vicinity.

And last, particularly if lasers over 5 milliwatt level are used, safety goggles must be available to the operator and to any person that might be near or working with the laser beam, during the alignment process for example. Home made safety glasses can be made with readily available KODAK WRATTEN SERIES filters from your local photography supply store. The filter numbers you would need are as follows:

For IR laser diodes : WRATTEN #87A or 87B
For Helium Neon : WRATTEN #40
For Helium Cadmium : WRATTEN #12 or #15
For Argon : WRATTEN #21 or #22

LASER DIODE WORK :

We would also like to acknowledge the laser diode work currently being done by Roger K6LMN, and Heinz OE6HS.

LASER EQUIPMENT SOURCES :

MEREDITH INSTRUMENTS
5035 N. 55th AV #5 / PO BOX 1724
Glendale, Arizona 85301
602-934-9387

EDMUND SCIENTIFIC
101 E. Gloucester Pike
Barrington, New Jersy 08007
609-573-6250

MWK Industries
198 Lewis Court
Corna, California 91720
800-356-7714

USING TV VIDEO CARRIERS TO MONITOR PROPAGATION

BY

AL WARD
WB5LUA

Haven't you ever wondered what shape the band was in without actually calling CQ on 144.200?? The introduction of the present beacon system years ago has helped immensely in identifying potential band openings but there are not really enough beacons on to actually identify openings to all areas. One of the reasons is the often heard statement "Beacons are great as long as they are not in my backyard!" It is difficult to have a moderate power beacon on both 6 and 2 meters running moderate power when it is in the same area as a handful of operators. The WB0CGH 1 watt 6 and 2 meter beacons in the northeastern DFW area are within 15 miles of AA5C and according to Greg, his receivers are on the threshold of pain! There is another solution and it happens to be nothing new. The use of both VHF and UHF TV video carriers can provide good reliable indicators of enhanced conditions. These video carriers have been used by numerous VHF operators for years and was addressed by Bill Smith in his earlier QST column in the 70's[1]. Keith Ericson also published a paper in the 1988 Central States VHF Society Conference Proceedings which addressed the use of the UHF video carriers[2] as propagation monitors. His paper also listed some of the UHF stations operational in the Midwest and Rocky Mountain areas of the US. With the new general coverage VHF/UHF receivers available on the market, the author felt that the subject needed a review for those new and old who have never tried video carrier DXing.

Each TV channel is assigned a 6 MHz wide allocation. The video carrier is situated 1.25 MHz above the bottom edge of each frequency allocation. Depending on the geographical location, there may be an offset of +10 kHz or -10 kHz assigned to each particular station. The purpose of the offset is to minimize potential interference. Most of the TV signal's power is in the video carrier which can be easily copied on a narrow band receiver capable of either cw or ssb reception. Because of the ability to receive the video carrier in a narrower bandwidth, an improvement in signal to noise ratio of up to 30 dB can be realized. Whereas a typical TV signal may only be seen up to 100 miles or so under normal conditions, the video carrier as received on a narrowband receiver can be heard at distances out to 350 to 400 miles! The trick is to find a clear channel in between the local channels with which to do some DXing.

Years ago Al Burson, K5WXZ, who was very active on 2 meter weak signal work back in the early 70s and before, made use of the channel 12 video carrier as his propagation indicator. Every evening the locals in the area, including myself, would anxiously await his report of potential tropo for the evening. Al built a 205.25 MHz converter that fed his low frequency communications receiver as a tunable IF. His antenna was a 4 wavelength yagi antenna at 70 ft. Al was able to monitor and identify with the help of the offsets, three carriers on a nightly basis. The channel 12 out of Clovis, N.M. had a negative offset, Hutchison, KS had a zero offset, and Jackson, Ms had a positive offset. A quick tune of channel 12 gave Al a real good indication of tropo in three directions. Unfortunately with the increase in TV activity in the DFW area, a local channel 12 has appeared making it very difficult if not impossible to DX anymore on channel 12!

Recently, Bill Smith, W5USM, who used to write "The World above 50 Mc" for many years,

suggested that I try to use my FRG-9600 general coverage VHF/UHF receiver to monitor some of the VHF channels. I took Bill's advice and made a dipole for channel 9, connected it to a spare piece of RG/17 that was already up my tower and soon found myself in business. In fact, I was able to monitor a number of VHF and UHF channels in neighboring states. It was obvious that even with the offsets , that it is very difficult to pinpoint the direction of each carrier. This was especially evident on VHF. It was obvious that a directional antenna is a must. For two reasons, I decided to put up a rotatable yagi for UHF. First off, UHF antennas are smaller! Second, it appears that it may be possible to find more "clear channels" on UHF. I side mounted a Radio Shack U-75 UHF yagi at 55ft complete with rotator. Results were excellent. Even without a preamplifier, I was able to consistently hear the video carriers from numerous UHF stations at distances out to nearly 400 miles with no enhancement in conditions. Having a general coverage receiver certainly offers more flexibility than if a converter had to be constructed for each channel that we desire to receive.

EQUIPMENT

The simplest approach to modern day TV video DX ing is to use one of the all band receivers manufactured by ICOM or Yaesu. Suggested receiver model numbers are listed here.

Yaesu	FRG-9600	tunes 60-905 MHz
ICOM	R-7000	tunes 25-2000 MHz
ICOM	R-7100	tunes 25-2000 MHz

The beauty of one of the general coverage receivers is the ability to listen to various TV video carriers on all VHF and UHF channels (The FRG-9600 only goes down to channel 3). The receivers listed above all tune narrow band modes such as USB, LSB, or CW with a 2.4 kHz bandwidth to allow discrimination of signals with different offsets. The FRG-9600 has 99 memories which include both frequency and mode. I chose to use memories 03 through about 51 to coincide with the actual TV channels 3 through 51. I also used memories 53 through 92 to correspond to the audio frequency of TV channels 3 through 42. Programming in the audio frequencies often comes in handy when trying to identify certain channels during a band opening. Quite honestly, one should probably be working the DX on the radio as opposed to the TV frequencies!

The simplest approach to a UHF antenna is the use of either of the Radio Shack antennas, such as the U-75, U-100, or U-120. I have been very happy with the U-75 which was easily side mounted along with an inexpensive 28 year old Alliance T-45 rotor. It is best to install a balun at the antenna and use coax to keep losses to a minimum.

A simplest approach to a preamplifier is one of the inline preamplifiers sold by RadioShack. The 15-1118 is a 10 dB gain unit while the 15-1108 is a 20 dB gain unit. Noise figure is not specified but would guess it to be in the 3 to 5 dB range. If you desire to build your own preamplifier, the Avantek/HP MSA-1104 MMIC makes a nice low noise, moderate gain, and high intercept point amplifier. A simple schematic is shown in Figure 1. The unit is designed to be run from an 8 volt supply which is available on the rear panel of the FRG-9600. Noise figure is in the 3.5 to 4 dB range with a gain of between 11 and 12 dB over the entire VHF/UHF TV frequency range. Be careful not to add too much gain in front of any of the general coverage receivers as the intermod created by the local TV stations could mask neighboring channels used for DXing.

The standard approach to tuning the video carriers would be to design and build a low noise downconverter with good dynamic range and pick either a vacant VHF or UHF channel to monitor. A general block diagram showing this concept is shown in Figure 2. 4 or 5 TV channels can be downconverted with a single LO to a general coverage IF receiver. I tested this concept by using either a

Mini-Circuits SBL-1 or a Vari-L CM-1 500 MHz mixer fed with a 540 MHz LO board from Down East Microwave. The use of a high pass filter to offer image rejection in front of the mixer allows the reception of channels 26 through 30 by using an HF rig with general coverage from 1 to 30 MHz. I tested the original concept with out any image reject filter and achieved good results. However, keep in mind that with a low IF such as 3.25 MHz, image rejection will be difficult to achieve with simple filters. The IF frequencies and the required offset can be set into memory and labeled the appropriate channels.

GETTING READY TO DX

A list of channel allocations for both VHF and UHF can be found in the The TV and Cable Factbook (services volume) available from your local library or TV station or Cable company. It is published by Warren Publishing, Inc (ISBN 0911- 486-44-5, ISSN 0732-8648). Their address is 2115 Ward Ct, N.W, Washington, D.C. 20037. This is a high priced publication so it would be best to check local sources first. Keep in mind that these listings are just allocations and it would be best to check out the actual existence of the station by a telephone call to the station or to a fellow amateur in the area.

In order to assist in setting up a general coverage receiver for the various channels, I have included in Figure 3, a list of the video carrier and sound carrier frequencies for each of the VHF/UHF channels. I then used the TV and Cable Factbook listing to pick various stations and offsets. I summarized a list of possible stations and offsets for channels 14 through 62. This is contained in the appendix and is applicable for the Texas area. Using the Factbook, a listing can be tailored for a particular location. In order to get a better understanding as to the locations and offsets of the various channel 14 TV stations near the DFW metroplex, I plotted the locations on the map shown in Figure 4. Note that with a good directional antenna with some front to back ratio, it would be possible to detect enhanced conditions to the north, east, and southwest. Even though all 3 stations are on the same offset, it is still possible to hear a slight offset between each station as the antenna is rotated. By law all stations must be within 1 kHz of the assigned carrier frequency. However, I don't think that is always the case!

HOW DOES IT WORK?

On the morning of March 9, I was monitoring both channels 41 and 47 in the Tulsa, Ok area. Distance from the DFW area to Tulsa is about 230 miles. Normally, both channels are near the noise level but copyable. This morning both signals were nearly full scale on the FRG-9600 so I decided to give W5DFU a call so we could try 3456 MHz. 432 MHz signals were 59plus so we tried 3456.1 MHz and established a contact fairly easily. Warren was running only 2 watts to a 16 inch horn antenna while I was running a 5ft dish and about 50 watts. On 3456 MHz, signals peaked about 9am and were lost shortly after that time. Channels 41 and 47 were still pretty strong even after we lost 3456 MHz and proceeded to fade about an hour later.

The enhanced reception of channel 38 in New Orleans at about 350 miles has also given notice of good tropo conditions into Florida.

Another interesting propagation challenge is aircraft scatter. I have previously used this technique to work KX0O at Pikes Peak at 620 miles on 902 and 1296 MHz. I decided to try to monitor various Colorado carriers to see if I could correlate the reception of these carriers with known air flights between DFW and Denver. Well, initially I failed. I tried to listen to Denver based channels with no success. But, according to the recent work that Kent Britain did on aircraft scatter, Denver is not high enough or maybe Dallas is not high enough. None the less, it is not possible according to the theory. I am presently trying to find carriers somewhat closer to home. Channels 41 and 50 in Albuquerque, NM look promising, however, channel 41 is competing with channel 41 in Tulsa and San Antonio. An interesting challenge! Once a

possible path is found, it would be most interesting to let the receiver run all day while connected to a strip chart recorder to determine peak times. Next step would be to set up skeds with some potential stations. Sounds scientific!

Predicting sporadic E is best done by monitoring one of the lower VHF channels, i.e. ch 2 or 3. Observation of sporadic E on the higher channels will give an indication as to the MUF. Reception of sporadic E on channel 7 would certainly indicate that 2 meters is open.

Use of the video carriers for monitoring meteor activity can give an indication as to the success rate along a particular path. The VHF channels are best suited for this mode as the bursts will be longer lived than if UHF were used. The use of a strip chart recorder would also give an indication as to meteor shower peaks or even peak time for random meteors.

Other modes of propagation that could be researched with the help of the TV video carriers include aurora, lightning scatter, F2, and FAI. Any thoughts?

OTHER SERVICES

The National Weather Service broadcasts can also provide a source of propagation beacons. Three frequencies are in use across the country

162.400 MHz
162.475 MHz
162.550 MHz

In a large metroplex like Dallas/Ft.Worth, 2 of the 3 frequencies are in use leaving one for use as a propagation beacon. An inexpensive Radio Shack type receiver plus a 3 or 4 element yagi will provide a good indicator of tropo. The frequencies are a little high to be of much value in providing an early indicator of sporadic E as 2 meters will have already be open!

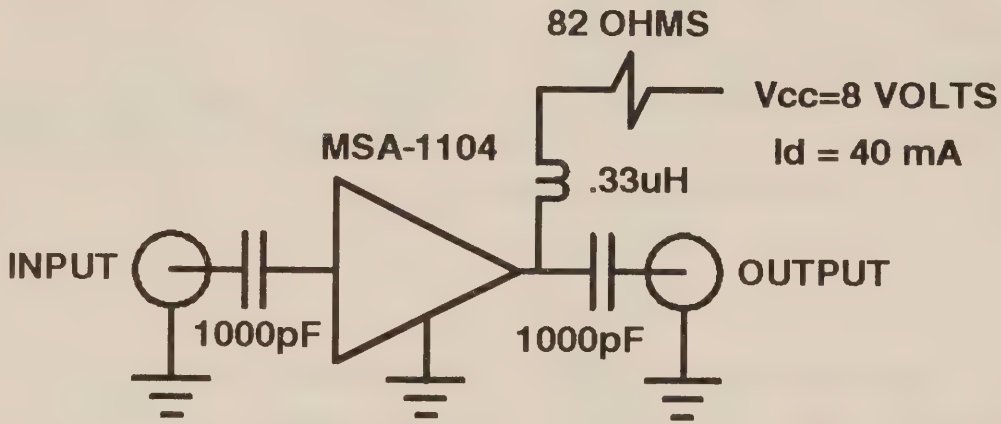
CONCLUSIONS

The TV video carriers can certainly provide insight into conditions on the VHF and above amateur frequencies. They can be used to study a multitude of propagation phenomena. With todays broad band ssb and cw receivers, it is possible to monitor a significant number of both VHF and UHF stations without elaborate downconverters and receivers.

REFERENCES

1. Bill Smith, "Using TV Station Video Carriers As Propagation Indicators" ,The World Above 50 Mc", QST, Feb 1972, pp 76-77
2. Keith Ericson, "UHF Propagation Beacons", Proceedings of the 22nd Conference of the Central States VHF Society Conference, 1988, pp152-157

MSA-1104 MMIC PREAMPLIFIER

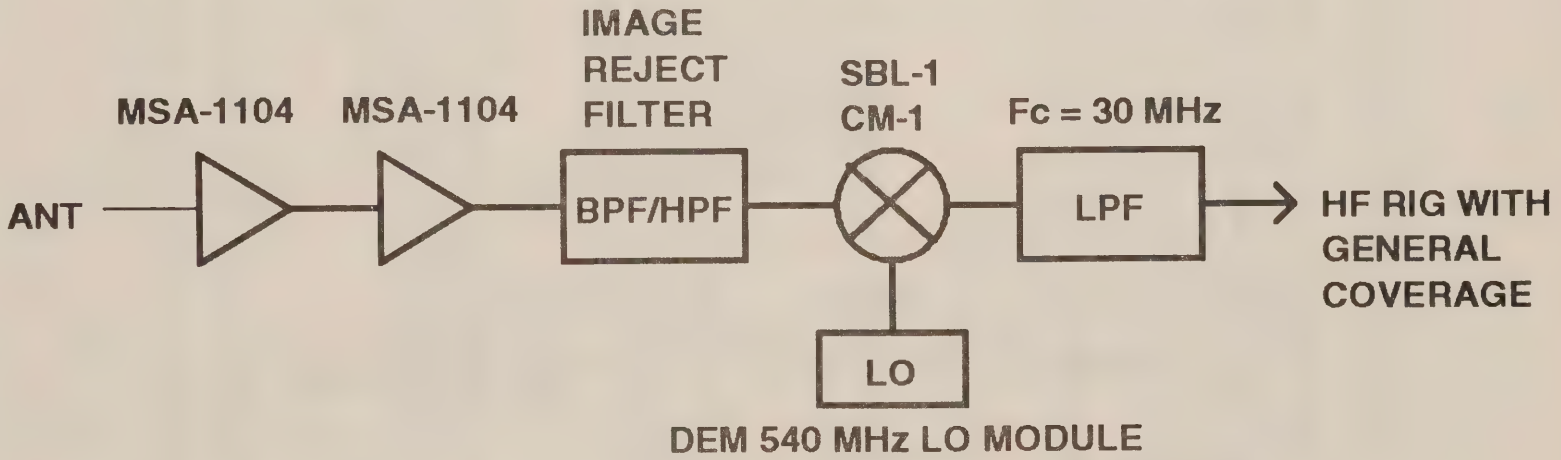


PERFORMANCE
NF = 3.5 TO 4 dB
G = 11 TO 12 dB
@ UHF

Figure 1

WB5LUA

USING A DOWNCONVERTER FOR RECEPTION OF VIDEO CARRIERS



CHANNEL	VIDEO CARRIER F	IF
26	543.25 MHz	3.25 MHz
27	549.25 MHz	9.25 MHz
28	555.25 MHz	15.25 MHz
29	561.25 MHz	21.25 MHz
30	567.25 MHz	27.25 MHz

NOTE: GENERAL BLOCKDIAGRAM SHOWING CONCEPT, LOWER IFs REQUIRE IMAGE REJECT FILTER WITH BETTER SELECTIVITY

WB5LUA

Figure 2

CHANNEL	VIDEO CARRIER (MHz)	SOUND CARRIER (MHz)
2	55.25	59.75
3	61.25	65.75
4	67.25	71.75
5	77.25	81.75
6	83.25	87.75
7	175.25	179.75
8	181.25	185.75
9	187.25	191.75
10	193.25	197.75
11	199.25	203.75
12	205.25	209.75
13	211.25	215.75
14	471.25	475.75
15	477.25	481.75
16	483.25	487.75
17	489.25	493.75
18	495.25	499.75
19	501.25	505.75
20	507.25	511.75
21	513.25	517.75
22	519.25	523.75
23	525.25	529.75
24	531.25	535.75
25	537.25	541.75
26	543.25	547.75
27	549.25	553.75
28	555.25	559.75
29	561.25	565.75
30	567.25	571.75
31	573.25	577.75
32	579.25	583.75
33	585.25	589.75
34	591.25	595.75
35	597.25	601.75
36	603.25	607.75
37	609.25	613.75
38	615.25	619.75
39	621.25	625.75
40	627.25	631.75
41	633.25	637.75
42	639.25	643.75
43	645.25	649.75
44	651.25	655.75
45	657.25	661.75
46	663.25	667.75
47	669.25	673.75
48	675.25	679.75
49	681.25	685.75
50	687.25	691.75
51	693.25	697.75
52	699.25	703.75
53	705.25	709.75
54	711.25	715.75
55	717.25	721.75
56	723.25	727.75
57	729.25	733.75
58	735.25	739.75
59	741.25	745.75
60	747.25	751.75
61	753.25	757.75
62	759.25	763.75
63	765.25	769.75
64	771.25	775.75
65	777.25	781.75
66	783.25	787.75
67	789.25	793.75
68	795.25	799.75
69	801.25	805.75
70	807.25	811.75
71	813.25	817.75
72	819.25	823.75
73	825.25	829.75
74	831.25	835.75
75	837.25	841.75
76	843.25	847.75
77	849.25	853.75
78	855.25	859.75
79	861.25	865.75
80	867.25	871.75
81	873.25	877.75
82	879.25	883.75
83	885.25	889.75

Figure 3, Video and sound carrier frequencies for VHF/UHF channels

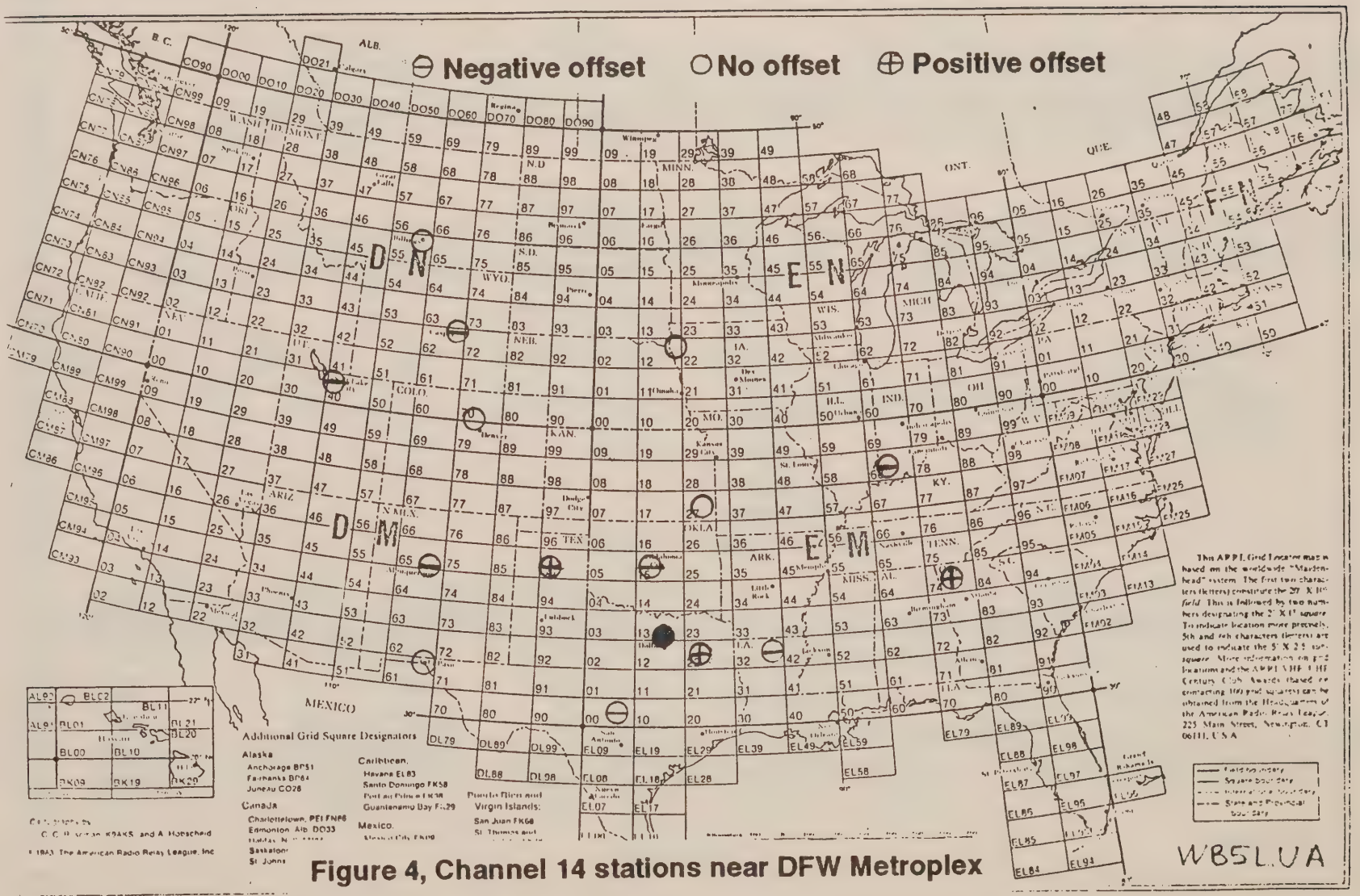


Figure 4, Channel 14 stations near DFW Metroplex

Appendix I , UHF Log compiled for DFW Metroplex

CH	MINUS OFFSET	ZERO OFFSET	PLUS OFFSET
14	Albuquerque,NM	Boulder,CO	Amarillo,TX
	Monroe, LA	El Paso, TX	Tyler, TX
	Oklahoma City, OK		
15		Lafayette, LA	
		Abilene, TX	
16	Little Rock, AR	Jackson, MS	Longview, TX
		Joplin, MO	Jackson, TN
			Lubbock, TX
17	Atlanta, GA		
	Texarkana, TX		
18	Texoma, OK	Sulphur Springs, TX	Salina, KS
	Wichita Falls, TX		
19			Victoria, TX
20	New Orleans, LA	Houston, TX	
	Enid,Sherman, TX	Denver, CO	
21	Ft. Worth, TX	Colorado Springs, CO	
	Roswell, NM		
22			
23	Albuquerque, NM	Garland, TX	
		Tulsa, OK	
		Brownsville, TX	
		Bryan, TX	
24	Wichita, Ks	Memphis, TN	Ft. Smith, AR
		Austin, TX	St.Louis, MO
25	Oklahoma City, Ok	Victoria, TX	Alexandria, LA
			Waco, TX
26		Houston, TX	Pueblo, CO
		New Orleans, LA	
27	Dallas, TX		
	Roswell, NM		
28	Corpus Christi, TX	Tampa, FL	
		Lubbock, TX	
29		Decatur, TX	Hobbs, NM
			San Antonio, TX
			Fayetteville, AR
30		Memphis, TN	St. Louis, MO
31		Denver, CO	Alexandria, LA
		Victoria, TX	
32	Pueblo, CO		Abilene, TX
	Kansas City, MO		
33	Baton Rouge, LA	Wichita, KS	Dallas, TX
		Shreveport, LA	Pensacola, FL

CH	MINUS OFFSET	ZERO OFFSET	PLUS OFFSET
34	Oklahoma City, OK Salina, KS Lubbock, TX		
35	Vicksburg, MS		Kerrville, TX
36		Atlanta, GA Austin, TX	Hutchison, KS
37			
38			New Orleans, LA
39	Houston, TX	Dallas, TX	Monroe, LA
40			Jackson, MS Duncan, OK
41	Kansas City, MO	Alexandria, LA	Albuquerque, NM Tulsa, OK San Antonio, TX
42	Austin, TX		
43		Bloomington, IL	Oklahoma City, OK Melbourne, FL
44	Waco, TX	Pensacola, FL Salina, KS	Baton Rouge, LA
45		Grove, OK Lawton, OK	Shreveport, LA
46	Atlanta, GA Temple, TX		
47		Tulsa, OK	
48			
49		Irving, TX New Orleans, LA	
50	Kansas City, MO	Tampa, FL Denver, CO Albuquerque, NM	Memphis, TN
51	Longview, TX	Jackson, MS	
52	Ft.Worth, TX	Oklahoma City, OK	

CH	MINUS OFFSET	ZERO OFFSET	PLUS OFFSET
53		Tulsa, OK	
54		Austin, TX	Longview, TX
55		Lake Dallas, TX	
56		Melbourne, FL	
57			
58		Dallas, TX	
59		Denver, CO	
60		Tyler, TX	San Antonio, TX
61	Chattanooga, TN	Houston, TX	
62			Oklahoma City, OK

Aircraft Scatter

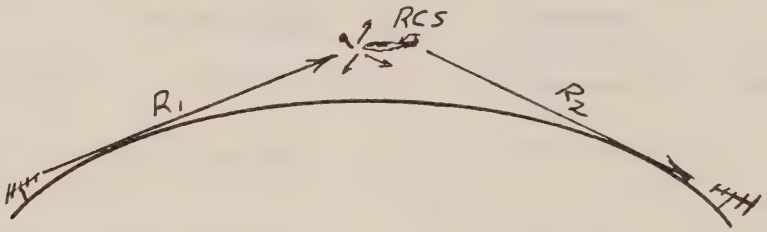
Kent Britain WA5VJB

This has been a very interesting project combining long talks with RADAR experts and AirLine Pilots. My biggest challenge was converting the Bi-Static RADAR Range Equation into a more usable form. A Bi-Static RADAR is one where the transmitter and receiver are not located at the same site.

Bi-Static RADAR Range Equation:

$$(R_T R_R)_{MAX} = \left(\frac{P_T G_T G_R \lambda^2 \sigma_B F_T^2 F_R^2}{(4\pi)^3 K T_S B_n (S/N)_{min} L_T L_R} \right)^{1/2}$$

In developing a simplified form of this equation, I must greatly thank Harold Reasoner, K5SXK Vernard Nicely, K5JVK and Mr. Rick Wood for their help. In this simplified form, we have path loss to the aircraft, a factor for how well the aircraft reflects, path loss to the second station, and a combination factor that allows for frequency and several constants.



R or the Path Loss in dB:

This is the path loss from the Transmitter to the Aircraft, or from the Aircraft to the receiver. Typically this will be the same number, but the equation still works nicely when the aircraft is closer to one station.

Relative Path Loss: (Based on P-Band RADAR)

Miles	25	50	100	150	200	250	300	500	600
dB Loss	92	98	104	107	110	112	114	118	120

Frequency Correction Factor:

This corrects for the path loss difference between bands and cleans up several constants.

Frequency Correction:

Band/MHz	50	144	222	432	902	1296	2304	3456	5760	10,368
dB Factor	18	27	31	36	43	46	51	54	57	63

Aircraft RCS:

This is the typical or average forward scatter RADAR Cross Section for several common aircraft. The numbers are expressed in dB above a 1 Square Meter spherical target. Because we are calculating Path Loss, and a bigger airplane has less path loss, these are shown as negative values.

Aircraft Factor:	727, 747, DC-10, B-52 etc.	-20 dB
	Lear Jet, F-15 etc.	-10 dB
	Low Observable U-2, B-2, SR-71 etc.	0 dB (Or Less)

So lets' put these numbers together and calculate a 600 mile QSO bouncing off a 747 near the mid-point for 144 MHz.

Path Loss = R(300 Miles) + RCS + R(300 Miles) + Correction Factor

= (114) + (-20) + (114) + (27)

= 235 dB

If we compare this to 251 dB for EME path loss, then we see than an SSB QSO is just possible between EME capable stations, or a pair of 1 KW stations using single Yagi's could just make it on CW.

This time we'll use 10 GHz over a 200 mile path and another Jumbo Jet at the midpoint.

Path Loss = (104) + (-20) + (104) + (63) or 251 dB

A pair of 10 Watt CW stations using 30 dBi (18") dishes and 3 dB Noise Figures works out about right. A little extra is allowed for Doppler Smearing of the signals.

The Ultimate Aircraft Scatter QSO:

"Aurora" at 100,000 ft. using 144 MHz for a 1000 mile QSO.
(The plane code named "Aurora" is why they scrapped the SR-71's!)

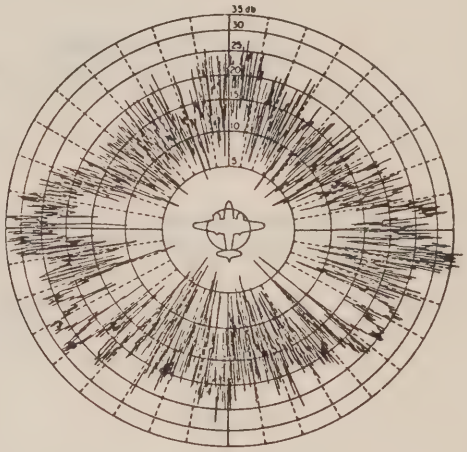
Path Loss = (118) + (0) + (118) + (27) or 275 dB

This is 24 dB higher than EME, it would take a pair of W5UN's for this QSO.

Very quickly there is a tendency to over analyze range vs. station capabilities. This is also why I don't have the factors figured to fractions of a dB.

While +20 dBSM may be a typical value for an airliner, the instantaneous value can vary tremendously. Old hands in RADAR will tell you this is why the range of a RADAR is figured with a Probability of Detection.

This is a 50 year old RCS plot of a B-26. The reflected signal can quickly vary from +10 to -20dB with very slight changes in angles. So expect the signals to quickly flutter up and down.



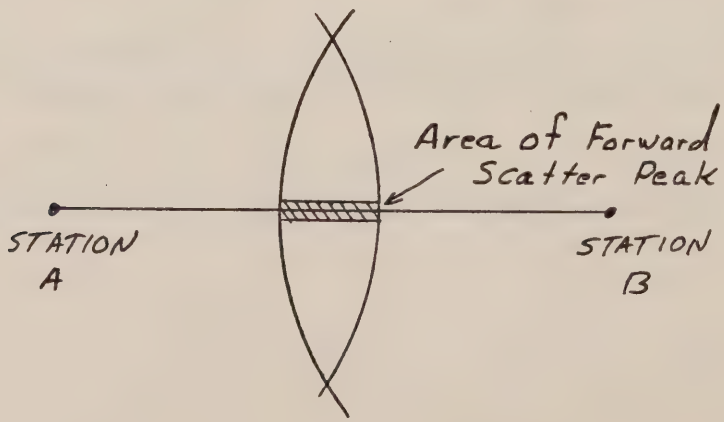
Path losses are for one aircraft. It is possible to have more than one aircraft in your common volume and pick up a few dB. But this kind of spacing makes Air Traffic Controllers nervous and is statistically unlikely for long paths.

$$\text{Forward Scatter Peak} = \sigma_f = \frac{4\pi A^2}{\lambda^2}$$

Finally we have one last effect. As the aircraft passes through the exact midpoint of the path, there is a specular peak (Forward Scatter Peak) off the airframe. At this point the equations model the aircraft as a flat plate rather than a sphere. This peak can add another 20 to 30 dB.

The problem is the width of the peak. The width is less than 1 degree on 144 MHz, and only .05 degrees on 2304 MHz.

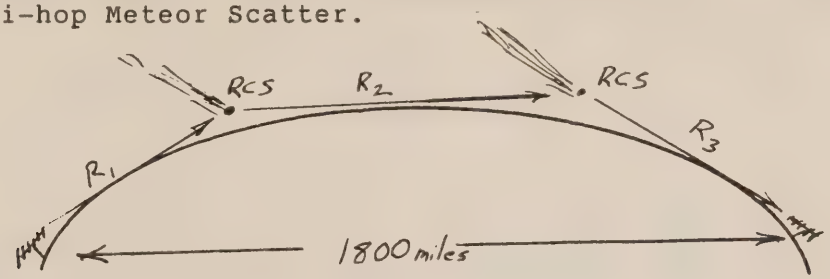
For 144 MHz over a 300 mile path, this specular peak is about 3 miles wide at the center and a jet would pass through it in about 30 seconds. At 2304, this area is only 1000ft wide and would last about 2 seconds.



Other Uses:

If you use 40 dBSM for RCS (That's 100 747's flying in formation) you get a good approximation of a Meteor Trail for 50 and 144 MHz.

This can also answer some of the questions regarding the possibility of 144 MHz multi-hop Meteor Scatter.



Path Loss = R1 + RCS + R2 + RCS + R3 + Correction Factor

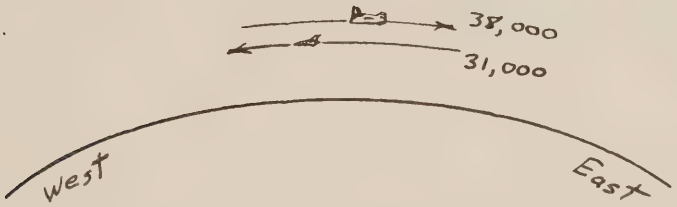
= (120) + (-40) + (120) + (-40) + (120) + (27)

= 307 dB

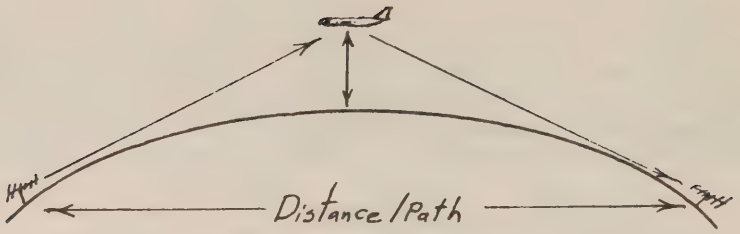
So even with a perfectly timed pair of "Blue Wizzers", we're looking at 50 to 60 dB more path loss than EME.

Wait for months or even years to get two "Blue Wizzers" in exactly the right spots, burning at exactly the same time, and we still need a couple of Kilowatts and 100 Yagi's at each end of the QSO.....

Path Geometry:



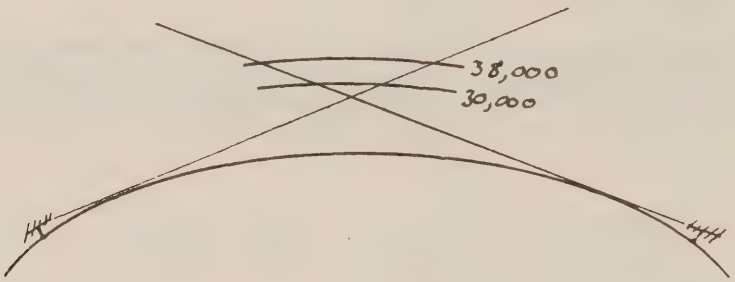
Many Many factors determine the altitude a pilot wants to fly at. 31,000 ft. for West bound and 38,000 ft. for East bound traffic are the most common altitudes for using/avoiding the Jet Stream. It takes quite a lot of fuel to climb to these heights, so only on trips of more than 400 miles is it worth the fuel to climb above 30,000 ft.



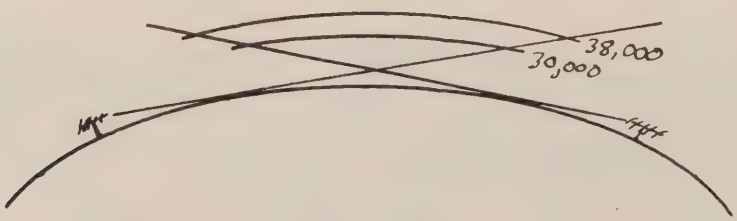
Height	Feet	10K	20K	30K	31K	38K	40K	50K	100K	200K
Path	Miles	320	440	520	530	600	620	680	1000	1300

These distances are calculated using 4/3rds Earth's Curvature and assume the antennas are 30 to 50ft. above the ground. 200,000ft is included as a typical value for meteor trails.

But these numbers represent the maximum possible distance with the aircraft visible to both stations for only a matter of seconds. This common window is so tiny, that the chances of an aircraft passing through it are very small.



Here we are looking at a 500 Mile path. If an airplane passes near the center of the window while traveling at 30,000ft., the plane will be in the window for about 2 min. If the plane is at 38,000ft. then the window will be open for 10 minutes.



OK, make it a 400 Mile path, then a 30,000ft. pass would be for 12 min. and the 38,000ft. pass could last for 20 minutes.

Conclusions:

For 144 MHz	200	300	400	500	600	Miles
Troposcatter Path Loss:	195	210	230	245	255	dB
Aircraft Scatter Path Loss:	211	221	227	231	235	dB

Here we are looking at Aircraft Scatter vs. normal Troposcatter losses. Over a 200 mile path, the Troposcatter signal is about 15 dB stronger than the refections off a 747. But at 500 miles, it's the Aircraft Scatter signal that's almost 15 dB stronger.

Some pretty long paths can be bridged between good stations. In the 400 to 600 mile range, Aircraft Scatter is the next best thing to a tropo opening. Just keep at it and wait for that Jumbo Liner to cruise by. And if you're lucky enough to catch that Forward Scatter Peak, signals will jump up another 3 or 4 S-units.

VHF/UHF Propagation Indicators

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The Memphis area now has amateur propagation beacons on nine bands which are intended to provide good propagation indicators for distant stations. More amateur beacons at the fringes of my station reception capability would be helpful. Until this happens, other propagation indicators can be substituted. This paper identifies potential indicators of terrestrial propagation and ranks them according to useability criteria. The VHF and lower UHF (up to 1300 MHz) spectrum segment will be considered.

To be an ideal indicator, transmitters should be moderate to high power, emissions should be coherent enough for narrow band reception, availability should be continuous and frequencies should be within range of amateur equipment. Suffice it to say that there are no ideal indicators. However, there are some meeting most of the criteria. A table listing potential propagation indicators is provided as a means to qualify and compare typical transmissions within various services. There are likely to be notable exceptions even within services deemed poor sources of propagation indicators.

Amateur service beacon transmitters provide fair indicators. The geographical dispersion could be improved through intelligent placement of additional beacons. At present there is no coordinated effort to enhance the service coverage. Also, amateur beacons are restricted to low power levels. The main advantage is the ease of reception with existing equipment. Frequencies are listed in the ARRL Repeater Directory.

Good propagation indicators exist in several other services, television/FM broadcast and aeronautical radionavigation (TACAN). TV/FM broadcast is easy to receive using native broadband modes. Better results can be obtained using narrow band reception such as with a 3 kHz SSB receiver. FM broadcast bandwidth is very wide but can still be detected in a narrow bandwidth during quiet audio periods. Even better results are obtainable using only the TV video carriers, which are easily receivable over significant distances using narrow band techniques. A table of TV carrier frequencies is provided. Since several different stations are sometimes receivable, a directional antenna is recommended. Without a directional antenna, it can be difficult to determine which direction signals are from until they become sufficiently strong to identify the program audio or video. Stations are listed in the North American Radio TV Station Guide, a Sams publication.

The other good indicator, TACAN, is not as easily received as TV but is better dispersed geographically. TACAN stations are intended for use by aircraft in flight so the transmitting antenna structure is near ground level. This will make it difficult to receive any stations more than a few miles away under flat propagation conditions. This "feature"

makes even close stations useful as indicators. Usually TACAN stations are colocated with VOR/ILS navigational aids, which also have potential use as propagation indicators. TACAN, UHF transmissions used by the military for distance and azimuth determination, uses a wide band pulse (the distance part) type of emission which is also amplitude modulated (the azimuth part). Morse identifiers are transmitted at frequent intervals. Location, channel and identifier letters can be obtained from aeronautical charts, which can be purchased at many airports or obtained free from pilots who regularly purchase updated charts and discard old ones. Two types of charts are particularly desireable, the Sectional and WAC types. Sectional charts are more detailed whereas WAC charts cover a wider geographical area. A table is provided to cross reference TACAN channel numbers or VOR/ILS frequencies to corresponding TACAN frequencies.

Equipment requirements depend on the extent of propagation indicators desired. Existing amateur station equipment is all you need to receive amateur beacons. TV/FM broadcasts are receivable using consumer equipment but with severely limited range under average band conditions. To receive TV video carriers in narrow bandwidths, a converter or receiver is necessary. Suitable receivers are available from Yaesu, ICOM, AOR, Grove and others. A less expensive choice is the Yaesu FRG-9600, which covers 60-905 MHz. Used ICOM R7000 receivers, covering 25-2000 MHz, are often advertised for sale in the Ham Trader Yellow Sheets. ICOM now markets the R7100 receiver, also covering 25-2000 MHz. Thr R7100 has 900 memories, enough to program all the TV video and audio carriers and TACAN channels with room to spare. Many of these receivers also allow connection to a TV monitor for TV picture reception. The R7100 allows wideband AM reception for use with TACAN pulse transmissions. Several years ago (two decades) I used a converted APX-6 transponder for TACAN reception, which still could be a cheap alternative approach. My best reception DX using the APX-6 and a ground plane was 109 miles, which my modern equipment has yet to best.

Antennas are available or can be constructed. Commercial wideband omnidirectional antennas are usually vertically polarized. Newtronics/Hustler DSX , ICOM and Comet all sell discone antennas. Creative designs has two models of VHF log periodic antennas which are intended for horizontal polarization. Common TV antennas are useable within their designed frequency ranges.

I hope that this paper will promote increased activity by encouraging all of us to look beyond the amateur bands for indications of enhanced propagation conditions. We should all do our part to eradicate for the "dead band syndrome". If you can suggest other services or specific signals not covered here as good propagation indicators, please share your discoveries with the rest of us.

Potential Propagation Indicators in the US VHF/UHF Spectrum

Frequency Range (MHz)	Typical Services	Typical Emissions	Radiated Power	Relative Constancy	Indicator Potential
30-50	Commercial/Government	FM	low	intermittent	poor
50-54	Amateur (beacons 50.06-50.08)	CW	low	continuous	fair
54-72	Broadcast	TV	high	continuous	good
72-76	Commercial/Government	FM	low	intermittent	poor
76-88	Broadcast	TV	high	continuous	good
88-108	Broadcast	FM (150 kHz)	low	continuous	good
108-118	Aeronautical navigation	AM	low	continuous	good
118-136	Aeronautical Communication	AM	low	intermittent	poor
136-138	Satellite	FM (50 kHz)	low	intermittent	poor
138-144	Government	FM	low	intermittent	poor
144-148	Amateur (beacons 144.275-144.300)	CW	low	continuous	fair
148-174	Commercial/Government	FM	low	intermittent	poor
174-216	Broadcast	TV	high	continuous	good
216-222	Commercial/Government	FM	low	intermittent	poor
222-225	Amateur (beacons 222.050-222.060)	CW	low	continuous	fair
225-400	Military aeronautical	AM	low	intermittent	poor
400-420	Government	FM	low	intermittent	poor
420-450	Amateur (beacons)	CW	low	intermittent	poor
450-470	Commercial/Government	FM	low	intermittent	poor
470-886	Broadcast	TV	high	continuous	good
886-902	Commercial (trunked/cellular)	FM	low	intermittent	poor
902-928	Amateur (beacons)	CW	low	intermittent	poor
928-962	Broadcast STL	FM (wide)	low	intermittent	poor
962-1215	Aeronautical radionavigation (TACAN)	AM (Pulsed)	moderate	continuous	good
1215-1240	Government	Pulse	low	intermittent	poor
1240-1300	Amateur (beacons)	CW	low	continuous	fair

Notes:
This is not intended to be a comprehensive breakdown of services.
Radiated average power levels are: low = < 1000, moderate > 1000/< 10,000, high > 10,000 watts.
Other considerations such as geographical dispersion and frequency reutilization should also be considered.
Generally, good indicators use moderate/high power, are continuous and are well dispersed geographically.
Broadcast station listings are published in book form.
TACAN frequencies can be derived from aeronautical chart data and a frequency table.
Amateur beacons are listed in The ARRL Repeater Directory.

US Television Transmitter Frequencies

Channel	Video	Audio
2	55.250	59.750
3	61.250	65.750
4	67.250	71.750
5	77.250	81.750
6	83.250	87.750
7	175.250	179.750
8	181.250	185.750
9	187.250	191.750
10	193.250	197.750
11	199.250	203.750
12	205.250	209.750
13	211.250	215.750
14	471.250	475.750
15	477.250	481.750
16	483.250	487.750
17	489.250	493.750
18	495.250	499.750
19	501.250	505.750
20	507.250	511.750
21	513.250	517.750
22	519.250	523.750
23	525.250	529.750
24	531.250	535.750
25	537.250	541.750
26	543.250	547.750
27	549.250	553.750
28	555.250	559.750
29	561.250	565.750
30	567.250	571.750
31	573.250	577.750
32	579.250	583.750
33	585.250	589.750
34	591.250	595.750
35	597.250	601.750
36	603.250	607.750
37	609.250	613.750
38	615.250	619.750
39	621.250	625.750
40	627.250	631.750
41	633.250	637.750
42	639.250	643.750

Channel	Video	Audio
43	645.250	649.750
44	651.250	655.750
45	657.250	661.750
46	663.250	667.750
47	669.250	673.750
48	675.250	679.750
49	681.250	685.750
50	687.250	691.750
51	693.250	697.750
52	699.250	703.750
53	705.250	709.750
54	711.250	715.750
55	717.250	721.750
56	723.250	727.750
57	729.250	733.750
58	735.250	739.750
59	741.250	745.750
60	747.250	751.750
61	753.250	757.750
62	759.250	763.750
63	765.250	769.750
64	771.250	775.750
65	777.250	781.750
66	783.250	787.750
67	789.250	793.750
68	795.250	799.750
69	801.250	805.750
70	807.250	811.750
71	813.250	817.750
72	819.250	823.750
73	825.250	829.750
74	831.250	835.750
75	837.250	841.750
76	843.250	847.750
77	849.250	853.750
78	855.250	859.750
79	861.250	865.750
80	867.250	871.750
81	873.250	877.750
82	879.250	883.750
83	885.250	889.750

Notes:
Stations may be staggered plus or minus 10 kHz.
Video frequencies are AM picture carriers, 1.25 MHz inside the channel.
Audio frequencies are FM sound carriers..
Video and audio frequencies are always 4.5 MHz apart in the US.
All channels are 6 MHz wide, including audio sidebands,
picture upper sideband and picture vestigal lower sideband.

TACAN DME Ground Transmitter Frequencies

Use	DME Channel	VOR (MHz)	DME (MHz)
Military	1		962
	2		963
	3		964
	4		965
	5		966
	6		967
	7		968
	8		969
	9		970
	10		971
	11		972
	12		973
	13		974
	14		975
	15		976
	16		977
TVOR	17	108.0	978
ILS	18	108.1	979
TVOR	19	108.2	980
ILS	20	108.3	981
TVOR	21	108.4	982
ILS	22	108.5	983
TVOR	23	108.6	984
ILS	24	108.7	985
TVOR	25	108.8	986
ILS	26	108.9	987
TVOR	27	109.0	988
ILS	28	109.1	989
TVOR	29	109.2	990
ILS	30	109.3	991
TVOR	31	109.4	992
ILS	32	109.5	993
TVOR	33	109.6	994
ILS	34	109.7	995
TVOR	35	109.8	996
ILS	36	109.9	997
TVOR	37	110.0	998
ILS	38	110.1	999
TVOR	39	110.2	1000
ILS	40	110.3	1001
TVOR	41	110.4	1002
ILS	42	110.5	1003

Use	DME Channel	VOR (MHz)	DME (MHz)
TVOR	43	110.6	1004
ILS	44	110.7	1005
TVOR	45	110.8	1006
ILS	46	110.9	1007
TVOR	47	111.0	1008
ILS	48	111.1	1009
TVOR	49	111.2	1010
ILS	50	111.3	1011
TVOR	51	111.4	1012
ILS	52	111.5	1013
TVOR	53	111.6	1014
ILS	54	111.7	1015
TVOR	55	111.8	1016
ILS	56	111.9	1017
HVOR	57	112.0	1018
	58	112.1	1019
	59	112.2	1020
	60	112.3	1021
	61	112.4	1022
	62	112.5	1023
	63	112.6	1024
	64	112.7	1151
	65	112.8	1152
	66	112.9	1153
Military	67		1154
	68		1155
	69		1156
	70		1157
	71		1158
	72		1159
	73		1160
	74		1161
	75		1162
	76		1163
HVOR	77	113.0	1164
	78	113.1	1165
	79	113.2	1166
	80	113.3	1167
	81	113.4	1168
	82	113.5	1169
	83	113.6	1170
	84	113.7	1171

Use	DME Channel	VOR (MHz)	DME (MHz)
HVOR	85	113.8	1172
	86	113.9	1173
	87	114.0	1174
	88	114.1	1175
	89	114.2	1176
	90	114.3	1177
	91	114.4	1178
	92	114.5	1179
	93	114.6	1180
	94	114.7	1181
	95	114.8	1182
	96	114.9	1183
	97	115.0	1184
	98	115.1	1185
	99	115.2	1186
	100	115.3	1187
	101	115.4	1188
	102	115.5	1189
	103	115.6	1190
	104	115.7	1191
	105	115.8	1192
	106	115.9	1193
	107	116.0	1194
	108	116.1	1195
	109	116.2	1196
	110	116.3	1197
	111	116.4	1198
	112	116.5	1199
	113	116.6	1200
	114	116.7	1201
	115	116.8	1202
	116	116.9	1203
	117	117.0	1204
	118	117.1	1205
	119	117.2	1206
	120	117.3	1207
	121	117.4	1208
	122	117.5	1209
	123	117.6	1210
	124	117.7	1211
	125	117.8	1212
	126	117.9	1213

Notes:
TACAN - TACtical Air Navagation
DME - Distance Measuring Equipment
TVOR - Terminal VHF OmniRange
ILS - Instrument Landing System
HVOR - High altitude VHF OmniRange

HISTORICAL METEOR STORMS

by Joseph L. Lynch, N6CL

There are two events that stand out in the history of meteor shower caused propagation. The first, the Giacobinid-Tuttle Comet caused meteor storm, occurred on 9 October 1946. In a giant way it ushered in ham radio operator's relationship with meteor vaporization caused ionization.

The 6 meter ham band had been authorized only since May of that year and the operators who operated that band did not know exactly what to expect by way of propagation. They were aware of meteor caused ionization and called it the "shooting star" effect. However, no one knew what would happen the night of the forecasted meteor shower. Nevertheless, because of the hugh publicity surrounding it, hams were prepared to be on the band.

They were not disappointed. Ed Tilton, W1HDQ, the then editor of QST's "The World Above 50 Mc.", described in his December 1946 column[1], that the event "...produced such bursts, occurring over a wider area and for a longer period of time than ever before in the history of v.h.f. work."

Then, twenty years later, on the night of 16-17 November, operators on 2 meters had set skeds in anticipation of a better than average Leonids shower for that year. They, in turn were treated to what Sam Harris, W1FZJ, the then editor of the "World Above 50 Mc." column[2] headlined "...(a) Shower of a Lifetime." He went on to report that "Hundreds of contacts were made by calling CQ, or by breaking stations when their skeds were completed, as most were in the first minute or two of prearranged calls." The storm that lasted less than two hours did for 2 meters what the Giacobinid storm did for 6 meters in the way of VHF propagation generated by meteor vaporization caused ionization. Truly, these were once in a lifetime events for many VHF operators.

The Invisible Meteor Shower

What these two storms had in common were publicity and visibility. However, the largest meteoroid storm ever observed was never known to have been seen by anyone.

Detection of the storm first came by way of the moon.

During the late 1960's Apollo astronauts left seismometers on the moon. There

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[1]Ed Tilton, W1HDQ, QST, vol. 30, December 1946, p. 43.

[2]Sam Harris, W1FZJ, QST, vol 51, January 1967, p 61.

were four passive seismometers arranged in somewhat of an equilateral triangle 1100 km on a side with two of these devices located 180 km apart on one of the corners. They gathered data between 1969 and 1977. In June 1975, they detected an anomaly that turned out to be a meteor barrage that lasted for approximately ten days.

Between January and March 1976, F. K. Duennebier and his associates at the University of Texas examined data from these devices for a period of 924 days encompassing 1 January 1973 to 17 July 1975. The results of their analysis were published in Science[3] magazine.

What they found were several random registrations of seismic activity on the moon's surface over the period analyzed. During that time they found significant registrations for the period of 20 June 1975 to 30 June 1975, with a peak day of 22 June 1975.

After determining that these events were indeed impacts and not moonquakes, these scientists concluded that the impacts were from a cloud of meteors that the moon had passed through during that time frame.

Following that conclusion, they set about to measure the density of the cloud. By comparing the measured data with the mass of the moon, they determined the mass of the cloud to be between 10^{13} and 10^{14}g.

They then compared their observations with known meteor showers and found that this event did not match anything known. Their conclusion was that this was a sporadic meteor shower that had "previously gone undetected."

Correlating VLF Data

Assuming that this storm must have had a corresponding effect on the earth, a group of Brazilian astronomers, headed by Pierre Kaufmann, examined VLF data for the same period. The results of their investigations were also published in an article in Science[4] magazine.

VLF records were chosen because of the effects meteor vaporization caused ionization had on the D and E layers of the atmosphere. The D-layer forms a waveguide effect on signals within the VLF frequency range, transporting them for long distances across the earth's surface. At the terminator line between daylight and darkness the D-layer dissipates. Because of this the signal would undergo a phase

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[3]F. K. Duennebier, Y. Nakamura, G. V. Latham, H. J. Dorman, Science, vol. 192, June 1976, pp. 1000-1002.

[4]P. Kaufmann, V. L. R. Kuntz, N. M. Paes Leme, L. R. Piazza, J. W. S. Vilas Boas, K. Brecher, J. Crouchley, Science, vol. 246, 10 November 1989, pp. 787-790.

shift due to the changes in altitudes between the D-layer (then dissipating) and the E-layer.

It was known that meteor vaporization caused ionization could affect this phase shift in the D- and E-layers. Additionally, it was also known that the phase shift change could be so dramatic that the D-layer would decrease in height above the surface of the earth. This shift in altitude would cause the signal traveling along the "waveguide effect" of the D-layer to appear to have shifted in phase. It was known that the E-layer could also be affected by such ionization. Therefore, Kaufmann and his associates concluded that examination of VLF reception records could reveal any meteor caused detectable effects on these layers of the atmosphere.

They examined records from several stations around the globe. What their observations showed were that signals that traveled transequatorially were affected by increased ionization of the D- and E-layers. However, signals that did not cross the equator showed little, if any effects.

Their observations also indicated that the ionization was at such a level as to top the Giacobinid-Tuttle comet caused meteor shower by three to nine times the intensity. Additionally, their findings indicated that the radiant of the shower was in the southern hemisphere in approximately the same location as the sun. Because of its position, it was a daytime shower, and therefore, not visible.

They also determined that peak days of activity were 22 June and 26 June. The first date corresponds to the peak day of the moon activity. However, the second day does not and they conclude that this peak could be an anomaly related to some other caused ionization of the earth's atmosphere.

Correlating VHF Data?

It was this author's opinion that if such an intense shower did occur, then, based on past records of on the air activity during intense meteor storms (Giacobinid-Tuttle in October 1946 and Leonids meteor shower of November 1966), there should be corresponding data in VHF records.

The most prolific and continuous records of operating data are in QST's regular "World above 50 MHz" column. Therefore, the columns surrounding the event were examined for correlating data.

Indeed, Bill Tynan's column[5] showed that sporadic-E type propagation occurred during these days, with especially intense reports of events having occurred on 22 June and 30 June.

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[5]Bill Tynan, QST, vol. 69, September 1975, pp. 78, 136, 138, and 140.

One of the most interesting reports was of a three way QSO on 22 June that Bill (then located in Maryland) had with K3AAY, and K8CAY, the latter being only 280 miles away, in West Virginia. By the wording in the column, he strongly believed that the mode of propagation had to be sporadic-E. He quotes other reports of very short skip contacts during the same day. Oddly, this short distance propagation was also referred to as typical during the Giacobinid-Zinner Comet caused shower.

Bill also reported on receptions made by Pat, WA5IYX, (near San Antonio, Texas) of numerous signals during the days indicated. Additionally, Bill quoted a report from W7NFC, in Athens, Oregon, that indicated contacts will all states in the W1, W4, and W5 call areas during the day of 22 June. He included other reports that specified that day and others during latter June and early July. Bill concludes these reports by observing that "...the day-of-days was June 22, with QSOs all over the country (being reported)."

However, these days are during the sporadic-E time frame and this activity could have been (and was) interpreted as sporadic-E caused propagation. As stated, 22 June seemed to be a key day for all three data. However, Bill does not report data that would correlate to the Kaufmann observed peak on 26 June. Could it be that many hams were on the air on Sunday, 22 June, and that few hams were on the air on Thursday, 26 June? Additionally, Bill reports tremendous activity on 30 June, while neither Kaufmann nor Duennebier report correlating data. Could data on this date be related to a sporadic-E event? Could sporadic-E events be occurring simultaneously with meteor storm caused ionization on any or all of these dates?

For as much meteor shower activity, there seems to be little other correlating amateur radio VHF data (absence of 2 meter reports, for example). The question is asked, "Could the amateur radio observations be incomplete because 'nobody was on the air?'" In conducting unrelated research, your editor looked back into his 6 meter log for the last three years and found that each Memorial Day weekend the band had been open. No matter that the dates of the weekend have floated. Without exception, the band was open during some time of the weekend. Was the band open because people were home and on the air or was the band being open and people being home coincidental?

Conclusion

This paper represents a preliminary investigation of the data that are available. This author requests that if anyone has correlating data surrounding the dates indicated, could he or she please contact this author and share such data. Among the questions raised concerns the anomaly of the Kaufmann reported peak of 26 June and the Tynan reported propagation on 30 June. Was there a SID (sudden ionospheric disturbance) or other solar event that affected Kaufmann's observation or was there a lack of data from amateur radio operators for that date? Was the events that occurred on 30 June strictly related to sporadic-E caused propagation? Data from readers of this report may help answer these questions.

Biography

Joe Lynch, N6CL, was first licensed as WV6PDE, in December 1960. In addition to his Extra Class amateur radio license, he holds an FCC General Radio Telephone commercial license (the old First Phone). He has an AS degree in Electronic Communication Technology from San Diego Community College, a BS Degree in Business Administration and Industrial Technology from San Diego State University and an MBA from Oklahoma City University. Joe has displayed a long term interest in propagation of radio waves, having published articles in QST ("The Maunder Minimum", July 1976 and "Cycle 21 -- Four Divergent Views", February 1977) and other publications. He has also co-authored (with Leo Sands) a book on ham radio entitled Most Often Asked Questions and Answers on Ham Radio. Currently, he teaches electronics and computer fundamentals for the FAA and Francis Tuttle Vo-tech in Oklahoma City. He is also the VHF Editor for CQ magazine.

Low-Down UHF/Microwave Antennas for High-Flying Satellites
by: Stan Wood, WA4NFY, and Dick Jansson, WD4FAB

Introduction:

The AMSAT Phase 3D satellite consists of a spacecraft structure, that many of us feel is nothing more than an orbiting antenna farm. The satellite will have transmitters, receivers and antennas for seven of the eleven of the Amateur communications bands from 0.029 GHz to 10.5 GHz. For the structural designer, it is quite a chore trying to find antenna designs for all of these bands, and to find space on the satellite to place all of them. There are at least two serious efforts underway to find the most suitable antennas for this application. This report covers the results one of these efforts for some of these needed antennas.

Spacecraft Limitations:

Fig.1 shows a generalized perspective view of the Phase 3D spacecraft, including some of the early concepts of the antennas to be placed on the top. The principal radiation direction is along the Z axis, the center line of conical adaptor, toward the top of the illustration. On the Phase 3D satellite we have the entire top surface available for RF capture area, a fact that has not gone unnoticed. This top area amounts to 3.90m², or about 42 ft². While there is a lot of surface area on the top of the spacecraft, there is almost no available height. Any antenna dimensions in the Z direction will need to be either miniscule or buried within the spacecraft bus structure. In other words, low profile antenna designs are needed.

The launch of AMSAT P3D into an initial transfer orbit and it's final placement into a 16 hour Molnia orbit places multiple requirements on the antenna system. Initially P3D will be spun on the Z axis to maintain stability for motor firing. The Z axis will be oriented 90° to the major axis of the orbit and in line with the plane of the orbit. Table 1 shows the link variables encountered in this final orbit.

Table 1, AMSAT P3D Orbit Parameters

Orbit hr	Phase	Range	Path Loss	Earth <
8 hr	128	49800 km	-185.5 dB	13.0°
7 hr	112	48900 km	-185.4 dB	13.5°
6 hr	96	46600 km	-185.0 dB	14.5°
5 hr	80	43000 km	-184.3 dB	15.0°
4 hr	64	38000 km	-183.2 dB	17.0°
3 hr	48	31500 km	-182.6 dB	20.0°
2 hr	32	23700 km	-180.2 dB	25.5°
1 hr	16	15800 km	-177.9 dB	38.5°
0 hr	0	5000 km	-165.5 dB	68.0°

This table shows the orbital Phase, Range, Path Loss at 1269 MHz, and the width of the Earth as seen from the spacecraft (Earth <). The maximum pathloss is -185.5 dB at apogee (Phase 128) with a minimum pathloss of -165.5 dB at perigee (Phase 0). The path loss varies 20 dB over an entire orbit.

When the spacecraft reaches the final orbit it will be despun and three axis stabilized using momentum wheels and magnetic torquing. The solar panels will be deployed increasing the power available by a factor of two to three. The spacecraft will rotate to point the +Z surface at the Earth for the entire orbit. All high gain antennas are fixed in the +Z direction. Antenna pointing is done by positioning the entire spacecraft during the orbit so that the high gain antennas can be used. To properly illuminate the Earth, variable gain antennas are required. At apogee the width of the Earth as viewed from the spacecraft is 13°. This limits the maximum gain of the antennas to 19 dBi, as higher gains would not allow proper illumination of the Earth. At perigee the width of the Earth is 68° and the maximum gain is 6 dBi for full illumination. A variable gain antenna with a range of 6 to 19 dBi would give optimum performance for the entire orbit. The effect of the 20 dB change in path loss would be reduced to only a 7 dB change. This variable gain operation does not mean that an absolutely uniform illumination of the Earth needs to be obtained at perigee, only that the signal at receivers on the illumination limb of the Earth will be no lower than the signal levels seen with the satellite is at apogee. The antenna arrays shown in Fig.1 will meet that objective and will be described.

Candidate Antennas:

While we cannot pretend to have examined every possibility for all of the antennas needed, the list is significant. For 0.029 GHz the choices are very limited. As this is also a limited use perigee beacon mode operation, the antenna does not need to be exotic, and the considerations have included a three

pole CP "X Beam" and a "dipole" consisting of gamma matching the solar panels as the dipole elements.

Another band that has proven to be troublesome is 0.145 GHz. The selections are also limited. The top surface of the spacecraft cannot be totally usurped for just 2m antennas (although there are *some* Amateurs that would like to see that configuration on the spacecraft)! Were we able to use the top surface and obtain usable height, we could design a 0.145 GHz array of turnstile antennas that would do pretty well, but this is not an option. The alternatives take the form of a single quadrature feed full wavelength loop antenna mounted in the middle of the open throat of the conical adaptor. The other candidates are in the form of ¼ or ½ wavelength three element stacked whip antennas that pop out from the sides of the spacecraft when the solar panels are deployed. Variable beamwidth performance can come from operating these two antennas in proper proportion of radiated power.

For the higher bands the antenna situation becomes considerably easier, as the area available is quite adequate for some really good performance. The considerations have been patches, turnstiles, recessed turnstiles, slots, and short circular horns. The trade offs for this list is complex, but we have concentrated on the most attractive of the bunch, the patch antenna. The 10.5 GHz band will clearly use waveguide horn antennas directly connected to their transmitters.

The Patch Antenna:

Patch antennas can be described as a thin square of conductor material, approximately ½ wavelength on a side, closely spaced above a larger reflector plane. The center point of this active element may be grounded using a vertical conductor. While not exact, this patch radiator can be thought of as a pair of stacked dipoles, spaced by ½ wavelength and backed by a reflector. The more correct description of the antenna is that it is a pair of ½ wavelength slot antennas, spaced ½ wavelength. Active element feed points can be from the center of an edge, or inward with corresponding impedance variations. Patch antenna active elements may be of almost any shape, including round, rather than square. When properly feed, patch antennas operate with good circular polarization (CP) radiation performance. In the CP operation, all edges of the patch are actively included in the performance "equation".

When antenna users come in contact with the concept of the patch antenna, it is often in the context of those versions constructed with printed circuit board (PCB) materials and employing microstrip feed techniques. While such methods permit some rather impressive arrays to be constructed, the efficiencies encountered are often as low as 50%, principally due to dielectric losses and reduced element size caused by the material dielectric constant. Patch antennas do not need to employ high dielectric materials in their construction, hence the references herein will be to "patch" rather than "microstrip" antennas, and will use air (or space vacuum) as the dielectric.

Our tests have shown that the construction of these patch antennas requires some careful attention to fabrication methods and dimensional details. We have found that square patch active elements need to be $\approx$0.47 wavelength on each side, while the round versions are 0.540 wavelength in diameter. Close control of element size is important. Another important dimension is that of the spacing of the element from the reflector, $>$0.01 wavelength. Spacings of less than 0.01 wavelength result in reduced efficiency. Our need to carefully control the spacing is causing us to seriously consider the use of some repeatable spacing media, such as an open cell low dielectric constant honeycomb material.

With the construction methods being employed, the feed impedance characteristics are somewhat different than those of the PCB microstrip antennas. 50Ω feedpoints have been found to be located at 0.078 wavelength from the center, while a 100Ω feedpoint is located at 0.115 wavelength from the center. These are good dimensions to know, as a simple ¼ wavelength coupling line of UG141 coaxial cable connected between quadrature 50Ω points, and with the main feed located at a 100Ω point will result in an overall 50Ω feed impedance and a circular radiation pattern for the patch. All coaxial cable feeds are terminated with the outer conductor connected to the reflector plane and the center conductor connected to the active element. The ends of the coaxial cable are located perpendicular to the reflector plane, and the outer conductor should be extended to within a close proximity to the active element.

The antenna gain of single element patch antennas, constructed as described, have been measured to be in the range of 8.5-8.8dBic. With this level of element performance, useful arrays can be formed with seven elements, providing overall gains of 16-19dBic, depending upon element spacing.

Rules for Patch Antennas:

1. Use only air dielectric. Air (or space vacuum) has the lowest loss and a dielectric value of unity. A dielectric constant, $\epsilon=1.0$, makes the patch element full size which gives maximum gain. Teflon with a $\epsilon=2.45$ reduces the size to 64% and with no loss reduces the maximum gain by 3 dB. This is caused by the wider beam width of the smaller patch.
2. Mount patch higher not lower. The height of the patch above the groundplane should be approximately two percent of the width of the patch. With air dielectric a half wave square patch should be a minimum 0.01 wavelengths above the groundplane. Lower heights result in higher Q and high currents resulting in higher losses.
3. Design for maximum bandwidth. The bandwidth of a patch antenna is direct function of it's height. The limiting factor is mutual H-plane coupling in a close spaced planner array. The higher the elements the greater the spacing required between elements. Minimum edge spacing for 20 dB isolation between elements is 0.12 wavelength for a height of 0.04 wavelength.
4. Use coaxial not stripline feed. Patch antennas and striplines are not compatible on the same dielectric material. Strip lines prefer a high dielectric substrate and minimum height to work properly. 50Ω strip lines also require a ¼ wave transformer to match the edge of a patch.

With these rules in mind a 0.435 GHz seven element circular patch array was designed for the Phase 3D Spacecraft. They are supported by a central grounding post and a dielectric honeycomb under each element. Each element is operated in a RHCP mode. Element center-center spacing is set at 0.655 wavelengths (450mm) and is limited by the size of the available top plate area of the spacecraft. The original, and most basic of these seven element arrays is a hexagonal pattern with the seventh element in the center of the array. The power to the center element is varied to control the gain of the array. With equal power to all elements, the array is set for maximum gain. With the center element running maximum power and the outer elements running minimum power the array is at minimum gain and maximum beam width. Computer models show a continuously variable gain range of 8.5-16 dBic by only changing the power to the elements. All elements are fed in phase and no phase changes are required.

The patch array for 0.435 GHz needs to have two of its elements repositioned to allow it to be fitted to the top of the spacecraft, as shown in Fig.1. While this variant of the seven element array does change the overall performance, the deviation is on the order of 0.5 dB, mainly in the azimuth uniformity of the pattern.

For the higher bands, the fully optimized seven element patch array can be employed, as the space occupied is not too demanding of the available area. Computer optimization studies show that the element spacing in the array can usefully be extended up to ≈ 1.0 wavelength, with corresponding increases in array gain, up to $\approx$ 19dBic, before the fringing effects increase the side lobe outputs to objectionable levels.

Analytic Studies:

In this effort, all orbital parameters have been determined using Franklin Antonio's *InstantTrack* and antenna parameters using Brian Beezley's *MNC 4.0* antenna analysis software. InstantTrack provided the orbital RF range, path losses and Earth size information. We have found that the *MNC* analyses to be useful for this effort, although the package was designed analyzing for wire antennas, and is definitely not designed to evaluate slot antennas, *per se*. "Substitute" equivalent wire antennas were used with *MNC* to achieve our analytic goals. All antennas were evaluated over an infinite ground plane, which is less of an approximation with the higher frequencies. We feel that despite all of these analytic limitations for analyzing our highly specialized satellite antennas, the Beezley *MNC* software has performed superbly and permitted us to achieve given some very good understandings of our Phase 3D needs.

The CP patch antennas were simulated using a two wavelength square loop with four feed points, each located at the center of the sides. Adjacent sides were feed in a quadrature relationship, producing right hand circular polarization. Each of the patch elements therefore consist of four analytic antenna elements. For a seven element patch array, the analysis uses a total of 28 "elements", see Fig.2.

Fig.3 shows the reduced gain and increased beamwidth performance achieved with the seven element array of Fig.2 employing variable power distribution between the center and outer six elements. This performance change is the result of increasing the power to the center element. Fig.4 shows the gain and side lobe performance of a seven element array with a center to center spacing of 1.0 wavelength.

For the specific antenna for 0.435 GHz to fit onto the spacecraft, the arrangement needed to be adjusted, as previously discussed, using center to center spacing of 0.655 wavelength. Fig.5 shows this arrangement, and Fig.6 shows the high gain analytic performance of this array.

Test Data:

The antenna test effort has been principally focused on 0.435 GHz operation, due to the availability of test instrumentation. The test conducted have consisted of feed impedance measurements and (separately) gain comparisons. Literally, this has been a back yard operation, with the two types of tests being done in the respective authors' rear lot territories.

For a start, we constructed a textbook EIA reference antenna. This is a dual dipole unit with the elements located ¼ wavelength over a 1.0 wavelength ground plane, a large piece of double sided printed circuit board. The antenna is rated to have a gain of 7.7 $\pm$0.15 dBd. This translates to a gain value of 9.8 dBi, and has been used to date with that value. Fig.7 shows the flat feed characteristics of the EIA reference antenna. (One could only wish that the low profile antennas had this kind of low Q performance, too.)

A 1/3 scale model of the Phase 3D spacecraft has been constructed to permit the testing of the 0.145 GHz antennas using 0.435 GHz RF instrumentation. Tests of the seven element 0.435 GHz array will also be done on this model, using 1.2 GHz test equipment.

A standard base for 0.435 GHz patch antenna tests was constructed. This base allowed the feed points to be readily adjusted, and permitted different patch elements to be attached for test. The initial tests were conducted with a patch element with a diameter of 370mm. In fact, while close, the element size was slightly small and the resonant frequency of 0.439 GHz was just off of the top of the satellite band, although located in the center of the range of our test equipment.

Detailed impedance measurements were employed to determine the operating bandwidth of the test antennas, and to insure that the antenna adjustments would result in acceptable feed characteristics. To this end we used a Hewlett Packard VHF Bridge, Model 803A. The generator was a Measurements, Inc., Model T-1034B signal generator, and the tuned detector was an Icom dual band transceiver, Model IC-32AT. The first two pieces of test equipment were real throw-backs to antiquity, but the entire assembly of equipment, our "poor man's network analyzer", worked very well, albeit time consuming to take a set of test data. Reducing the test data to meaningful terms, including VSWR, required the use of a high level spread sheet program, *SuperCalc5*, which permitted the full numeric analysis and plotting of the data. Test data was taken as Z-Θ information and converted to R+jX, reflection coefficients, and test cable VSWR as well as "rotating" out the cable length to obtain VSWR at the antenna.

Impedance measurements were made with the test antenna supported away from the operators in a relatively free field with a skyward orientation. Fig.8 shows the results of a patch antenna measurement with a linear polarization feed. Fig.9 shows the results with the same patch antenna using a circular polarization feed. It is interesting to note that the apparent VSWR=1.5:1 operating bandwidth of this antenna has nearly doubled, most probably due to the multiple tuned circuit effects of the combination of the CP and main feed connections.

Antenna gain measurements are somewhat more involved to make. Obtaining a relatively free field is generally consider to be the root of most testing problems. For these back yard tests, a helical source antenna was placed at 20ft. on a wooden tower. Test antennas were located nearer the ground on a dielectric support (a wooden support made of 2x4 lumber). The range was about 35ft., 15 wavelengths. Such a close proximity provides a healthy signal with little source power, allowing us to use a relatively simple, but accurate Boonton Microwatt Power Meter, Model 4200. The negative effect of such a close range is the size of the uniform power volume, which inhibits the use of side by side, direct comparison, differential power measurement of the performance of two antennas. Antenna

substitution methods were employed for the necessary comparison of the test and reference units. This required multiple measurements to insure the repeatability of the data.

Gain measurements showed that the linearly polarized patch antenna was -1.2 dB signal level below the EIA reference antenna, using a linear source antenna. For the tests of the CP patch antenna, a helical source antenna was used, and the patch measured +2.0 dB above the EIA reference antenna. This data implies that the linear patch antenna gain is 8.7 dBi, while the CP patch antenna has a gain of 8.8 dBic. Despite these two tests being conducted over a period of time, the comparison of the two sets of gain measurements is considered remarkable. Measurements of patch circularity against a switchable CP Yagi antenna show a circularity isolation of greater than 20 dB.

Summary:

These antenna efforts, conducted by RF non-professionals, have illustrated to us that reasonable analyses, measurements and tests can be done using unsophisticated equipment. One needs to substitute patience and ingenuity as replacements for "super" equipment and massive analytic tools. By not accepting the common place result, and being willing to dig into the unusual, coupled with a massive dose of time, we have pointed the way for a usable set of antennas for a number of the bands to be implemented on the AMSAT Phase 3D spacecraft. It is clear that the patch antenna can be employed in a high performance configuration for this demanding application.

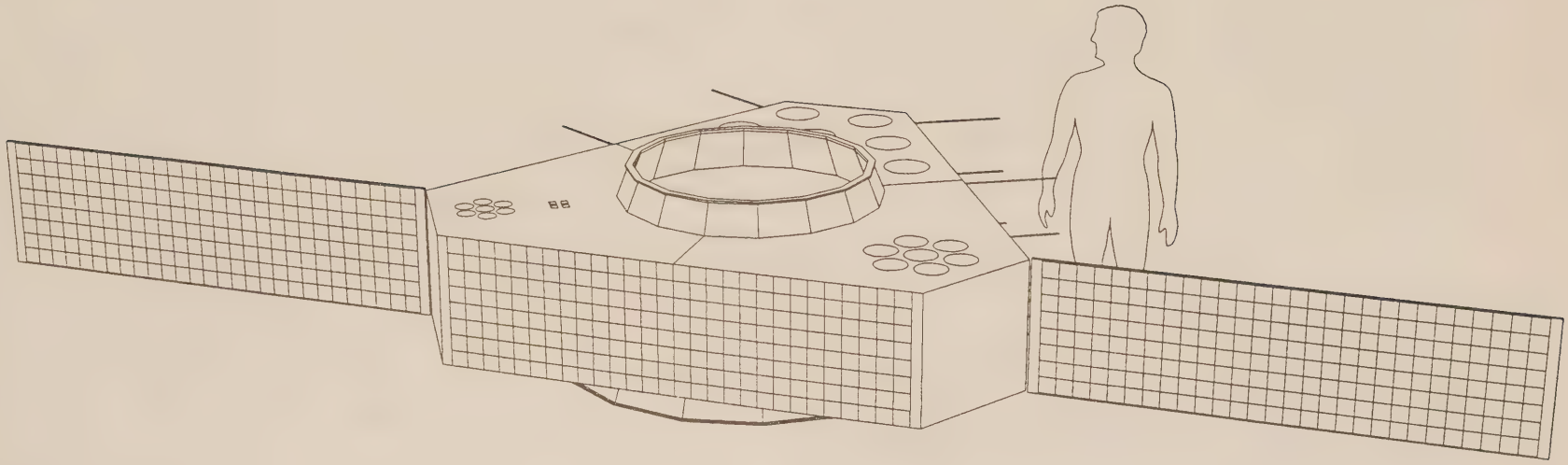


Fig. 1 AMSAT Phase 3D spacecraft configured as in orbital position.

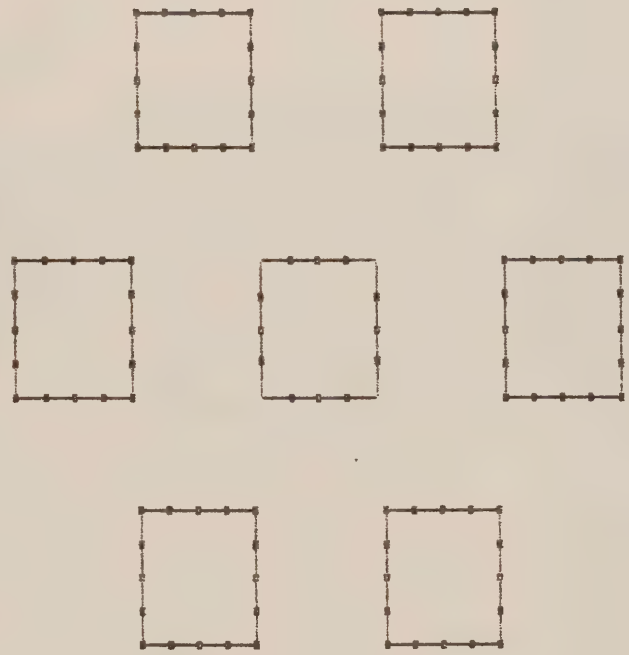


Fig. 2 Analytic model of seven element array with 1.0 wave. spacing.

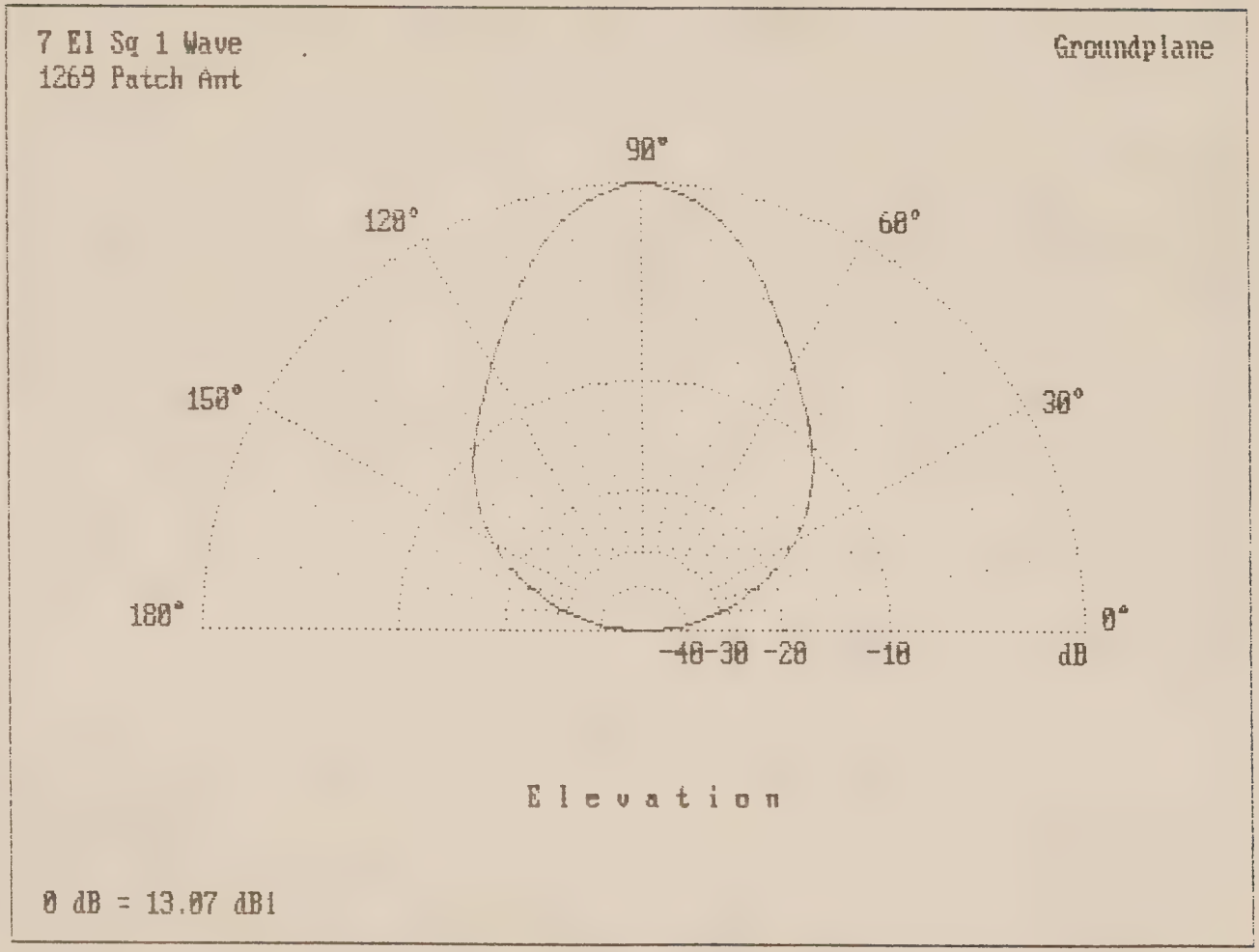


Fig. 3 Pattern and gain for seven element patch array, increased beamwidth.

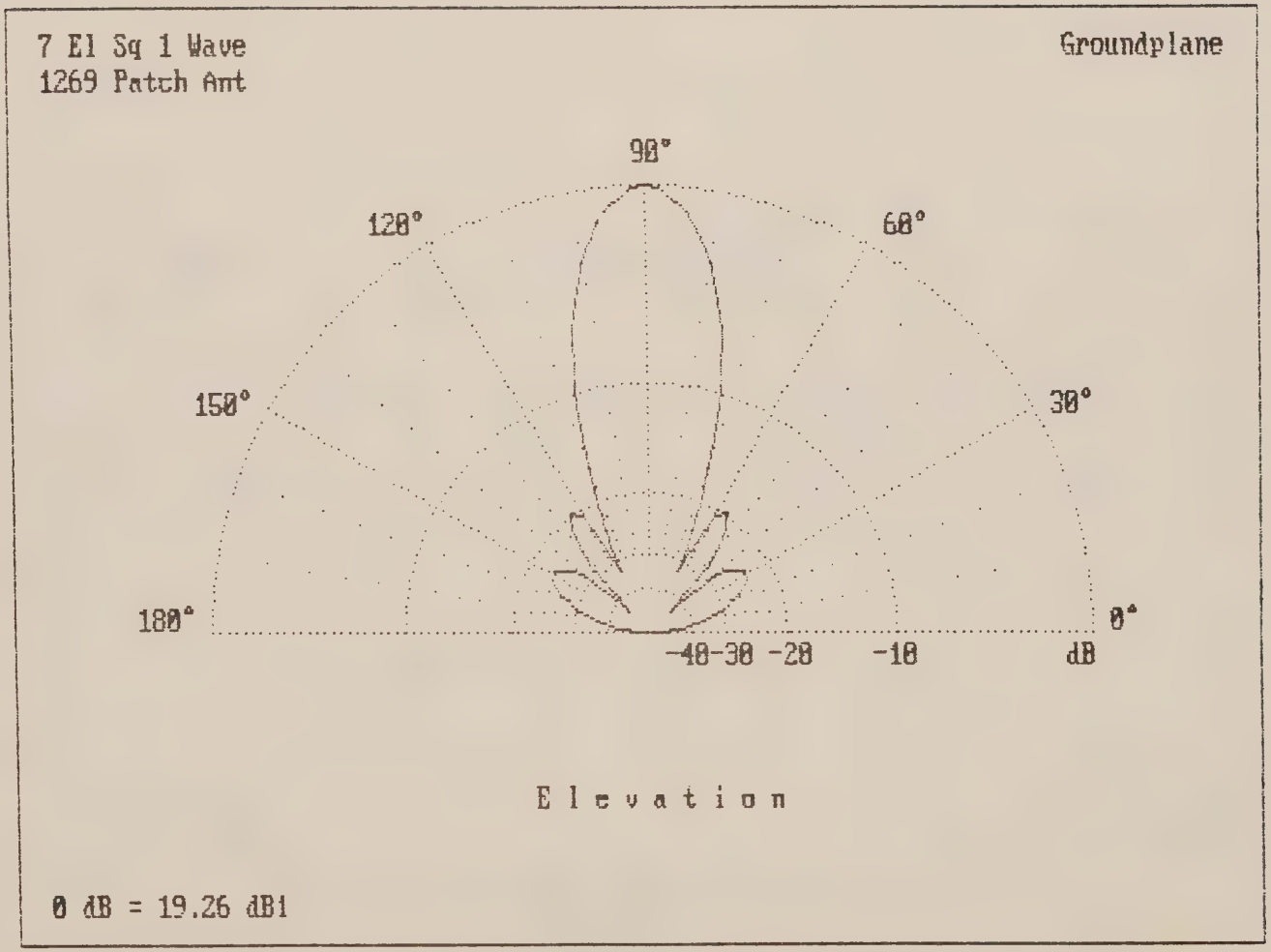


Fig. 4 Pattern and gain for seven element patch array, minimum beamwidth.

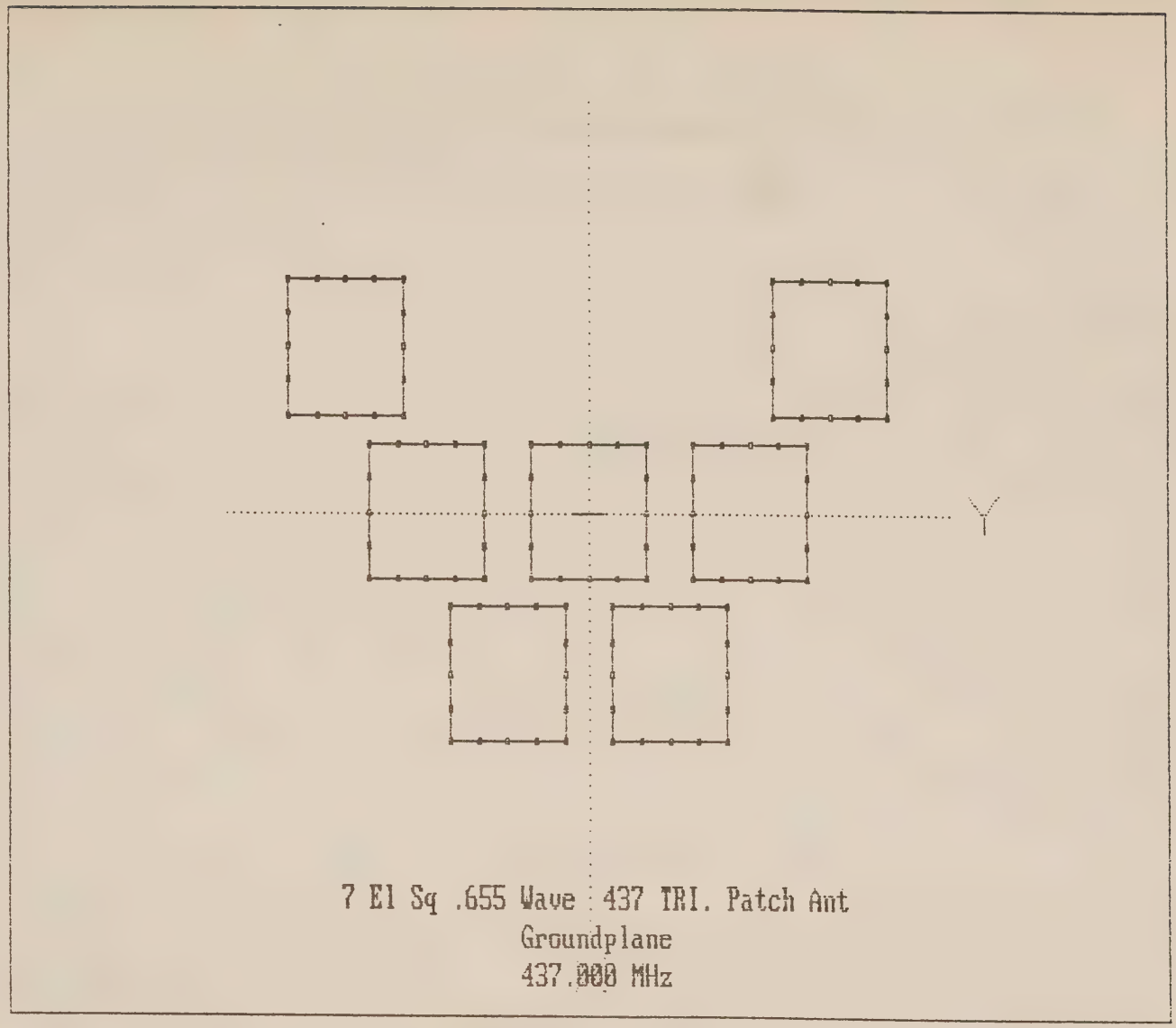


Fig. 5 Analytic model of seven element triangular array with 0.655 wave. spacing.

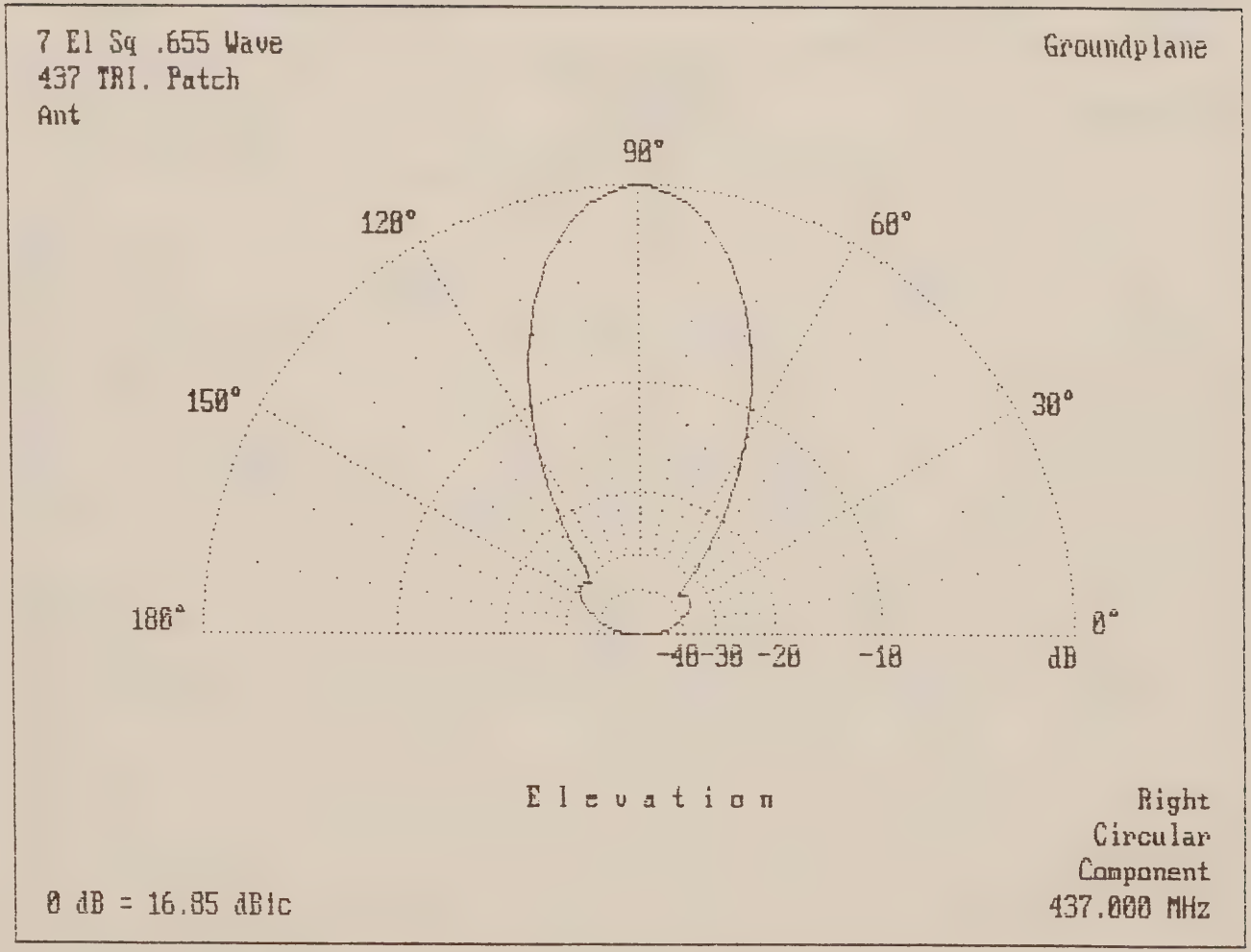
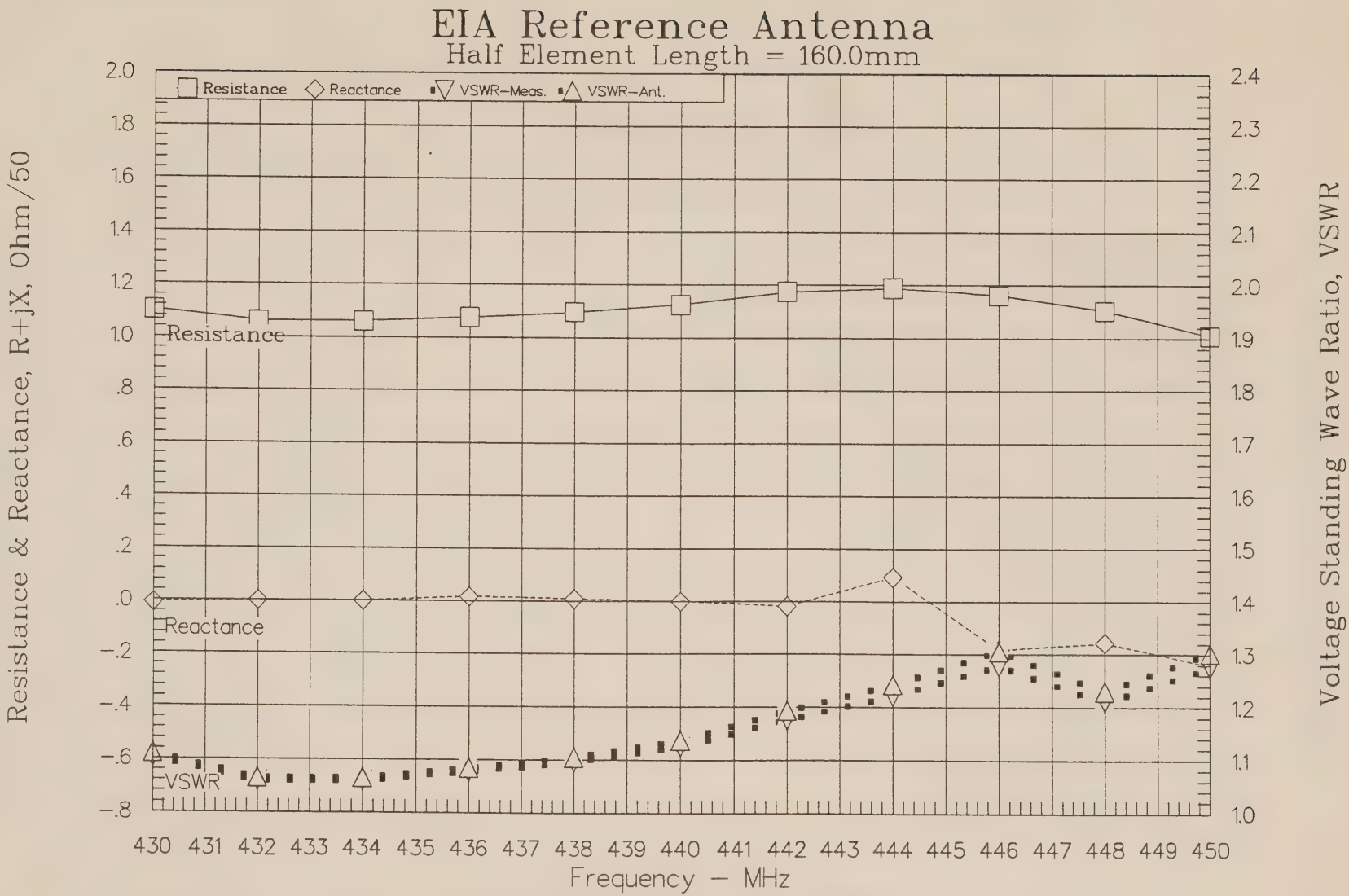
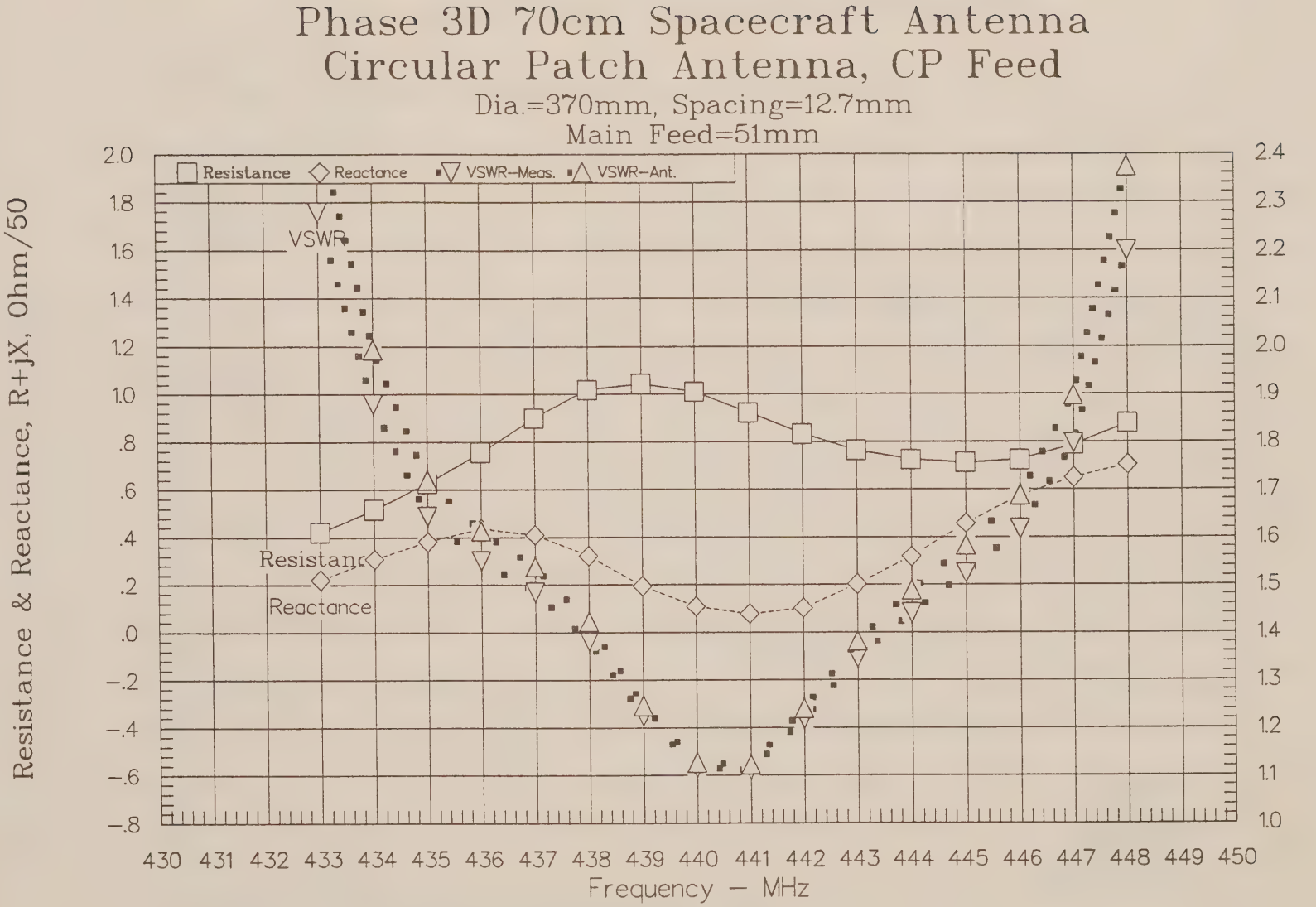


Fig. 6 Pattern and gain for seven element triangular array, 0.665 wave. spacing.



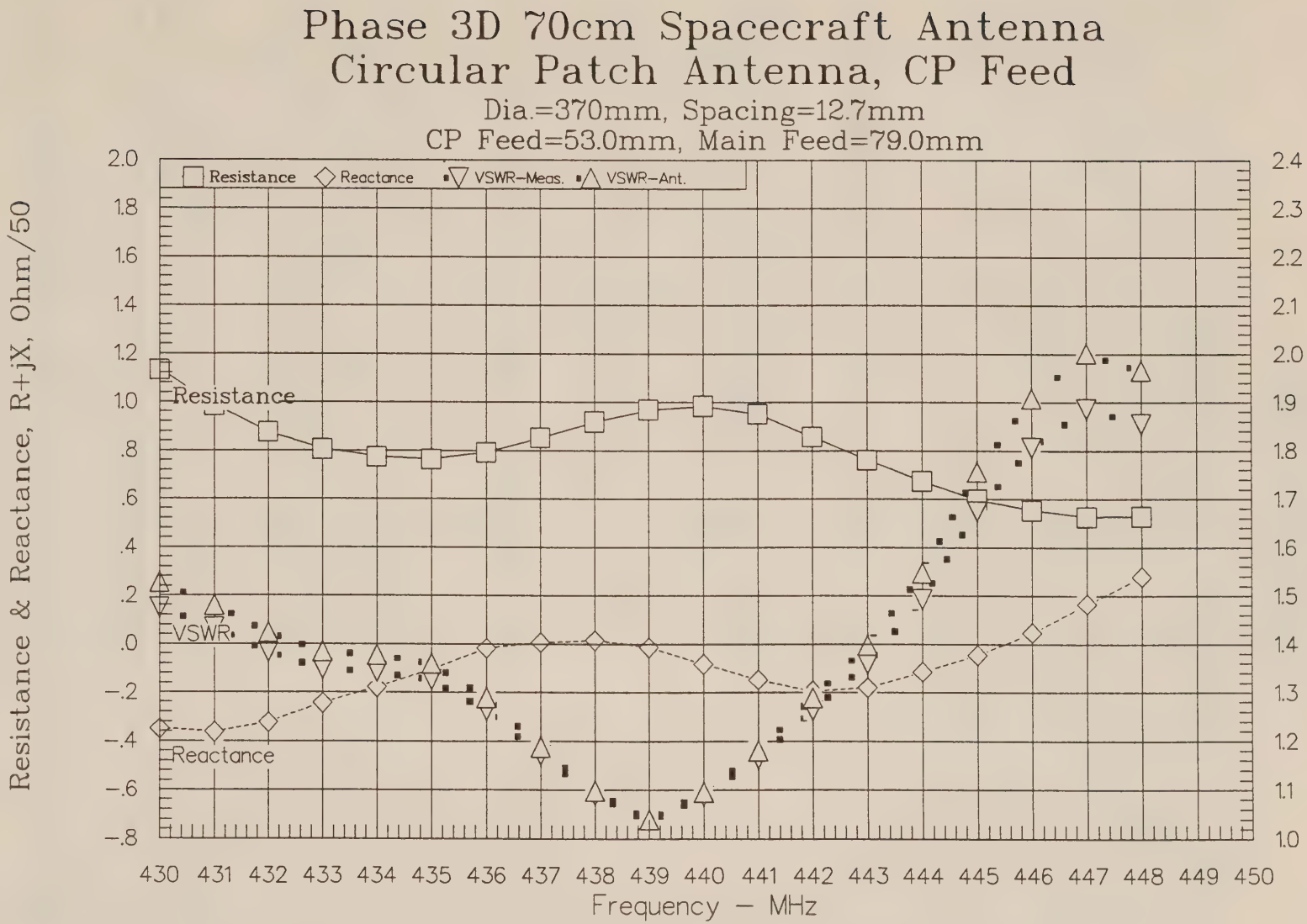
HP–803A VHF Bridge Measurement
3.33m Test Cable
01 March 1992

Fig. 7 EIA Dual Dipole reference antenna feed characteristics.



HP–803A VHF Bridge Measurement
3.33m Cable, Measurement to Sky
01 March 1992

Fig. 8 Single element patch antenna, linear polarization feed characteristics.



HP-803A VHF Bridge Measurement
3.33m Cable, Measurement to Sky
22 April 1992

Fig. 9 Single element patch antenna, circular polarization feed characteristics.

MOONDATA UPDATE - 1992-93

by Derwin King, W5LUU
7335 Wild Eagle Road
San Antonio, Texas 78255

The distance from the earth to the moon and cosmic noise from the direction of the moon substantially affect the quality of the EME (moonbounce) communication path. This has been recognized for several years (see: 1988 CSVHFS Conference Proceedings for the history and detailed explanations) and data on the signal to noise degradation (DGRD) due to these predictable variables have been made available in tabulations by the author appearing from time to time in EME publications and conferences as well as in more recent EME computer programs--i.e. PC Program by WA1JXN (1986 and later), Skymoon by W5UN. As a continuation of that service, Moondata for the remaining weekends of 1992 and for all of 1993 are listed in Table A. The data is for Sundays at 0000Z to provide a guide as to the expected conditions for the weekends. Day to day variations can be substantial. In addition to the degradation factor (DGRD) several other data pertinent to EME communications are also listed. For each date these include:

DEC. (deg.) - The moon declination in degrees north and south (-) of the equator. This is cyclical with an average period of 27.212221 days.

RA (Hrs.) - Right ascension (in hours) position of the moon against the sky background. RA cycle has an average period of 27.321662 days but any one period can vary from the average by a day or two.

144 MHz. Temp. (°K) - The amount of sky (cosmic) noise in the direction of the moon expressed as an effective temperature for 144 MHz. Effective temperatures for higher frequencies are lower - see Table B.

Range Factor (dB) - Indicates the increase in the EME path loss, in dB, due to the earth-to-moon separation distance being greater than the absolute minimum (348,030 km surface-to-surface).

DGRD, dB - Shows for both 144 MHz and 432 MHz the degradation in EME signal-to-noise, in dB, due to the sky noise plus the earth-moon separation distance for the moon position at that time and date. For 144 MHz this can vary over a range of 12 dB or more during a monthly lunar cycle. DGRD is referenced to lowest possible sky noise along the moonpath and the absolute minimum perigee distance.

Moon Phase - Shows new moon (NM) and full moon (FM) along with number of days before (-) or after (+) these events. At NM the sun noise causes a problem while at FM the more stable night time conditions can be advantageous.

Conditions - Summary of EME conditions as controlled by DGRD and new moon. Conditions may be worse due to ionospheric disturbance but not better than indicated.

TABLE A.

W5LUU Moondata - 1992
for Sundays at 0000Z

DATE 1992	DEC. Deg.	RA Hrs.	144 MHz TEMP. °K	RANGE FACTOR dB	DGRD, DB 144 MHz	DGRD, DB 432 MHz	MOON PHASE	CONDITIONS
July 12	-24.1	17.2	1218	1.92	9.0	4.1	FM -2	Very Poor
19	-2.2	22.8	244	2.29	3.3	2.6		Moderate
26	23.8	4.6	422	0.81	3.8	1.7		Moderate
Aug 2	-2.7	11.6	238	0.38	1.5	0.6	NM +3	Very Good
9	-23.6	17.9	2851	2.03	12.6	6.3		Very Poor
16	1.3	23.3	244	2.27	3.3	2.6	FM +3	Moderate
23	23.8	5.3	494	0.90	4.4	2.6		Poor
30	-6.0	12.1	269	0.29	1.7	0.7	NM +1.7	Good, But NM?
Sept 6	-22.4	18.5	1970	2.05	11.1	6.2		Very Poor
13	4.8	23.9	251	2.18	3.3	2.6	FM	Moderate
20	23.1	5.9	498	0.98	4.5	2.2		Poor
27	-9.1	12.6	313	0.34	2.2	0.9	NM +.5	Good, But NM?
Oct 4	-20.7	19.1	807	2.03	7.5	4.2		Very Poor
11	8.2	0.4	268	2.03	3.4	2.5	FM -1	Moderate
18	21.6	6.7	395	0.99	3.7	1.9		Moderate
25	-12.1	13.1	316	0.54	2.5	1.1	NM -1	Good, But NM?
Nov 1	-18.7	19.7	526	2.01	5.8	3.3		Poor
8	11.3	1.0	282	1.88	3.4	2.3	FM -2	Moderate
15	19.4	7.4	311	0.86	2.7	1.3		Moderate
22	-15.2	13.7	334	0.82	2.9	1.3	NM -2.5	Moderate
29	-16.5	20.2	367	2.03	4.5	2.7		Poor
Dec 6	14.0	1.5	295	1.78	3.5	2.3		Moderate
13	16.7	8.1	210	0.61	1.2	0.8	FM +3	Very Good
20	-18.0	14.4	376	1.09	3.6	1.7		Moderate
27	-14.2	20.7	336	2.11	4.2	2.7	NM +3	Poor

TABLE A. (Cont.)

W5LUU Moondata - 1993
for Sundays at 0000Z

DATE 1993	DEC. Deg.	RA Hrs.	144 MHz TEMP. °K	RANGE FACTOR dB	DGRD, DB 144 MHz	DGRD, DB 432 MHz	MOON PHASE	CONDITIONS
Jan 3	16.3	2.0	321	1.77	3.7	2.3		Moderate
10	14.0	8.8	182	0.32	0.4	0.3	FM+2d	***Excellent***
17	-20.3	15.1	426	1.25	4.2	2.0		Moderate
24	-11.5	21.2	339	2.22	4.4	2.8	NM+1d	Poor
31	18.3	2.5	357	1.82	4.2	2.5		Moderate
Feb 7	11.7	9.3	179	0.12	0.2	0.1	FM	***Excellent***
14	-21.8	15.8	496	1.26	4.8	2.2		Moderate
21	-8.3	21.8	307	2.31	4.1	2.8	NM-1	Poor
28	20.0	3.1	363	1.86	4.3	2.5		Moderate
Mar 7	8.3	9.8	185	0.11	0.3	0.1	FM-1	***Excellent***
14	-22.4	16.5	690	1.17	6.0	2.5		Poor
21	-5.0	22.3	254	2.35	3.5	2.7	NM-3	Moderate
28	21.4	3.8	362	1.82	4.2	2.5		Moderate
Apr 4	5.0	10.3	196	0.25	0.6	0.43	FM-3	***Excellent***
11	-22.5	17.1	1090	1.09	7.7	3.1		Very Poor
18	-1.6	22.9	244	2.32	3.4	2.6		Good
25	22.1	4.5	409	1.68	4.5	2.5	NM+3	Moderate
May 2	1.3	10.9	207	0.45	1.0	0.5		*Very Good*
9	-22.2	17.7	2401	1.11	11.0	4.9	FM+3	Very Poor
16	1.7	23.3	244	2.30	3.3	2.7		Good
23	22.3	5.2	489	1.45	4.9	2.5	NM+1.5	Moderate
30	-2.8	11.6	238	0.61	1.6	0.8		Very Good
Jun 6	-21.5	18.3	2586	1.24	11.4	5.6	FM+2	Very Poor
13	4.7	23.9	250	2.25	3.4	2.6		Moderate
20	22.0	5.8	503	1.20	4.8	2.5	NM	Poor
27	-6.8	12.2	287	0.67	2.3	1.1		Good
Jul 4	-20.3	18.9	1178	1.46	8.4	4.4	FM	Very Poor

TABLE A. (Cont.)

W5LUU Moondata - 1993
for Sundays at 0000Z

DATE 1993	DEC. Deg.	RA Hrs.	144 MHz TEMP. °K	RANGE FACTOR dB	DGRD, DB 144 MHz	DGRD, DB 432 MHz	MOON PHASE	CONDITIONS
Jul 11	8.0	0.4	266	2.25	3.6	2.7		Moderate
18	21.1	6.5	424	0.98	4.0	2.0	NM-1.5	Moderate
25	-10.5	12.9	313	0.61	2.5	1.2		Good
Aug 1	-18.5	19.5	606	1.69	6.0	3.2	FM-1	Very Poor
8	10.3	0.9	281	2.28	3.8	2.7		Moderate
15	19.8	7.0	364	0.88	3.3	1.6	NM-3	Moderate
22	-13.6	13.6	328	0.47	2.5	1.0		Good
29	-16.1	20.1	371	1.89	4.4	2.6	FM-3	Moderate
Sep 5	12.9	1.5	295	2.31	4.0	2.8		Moderate
12	18.0	7.6	291	0.89	2.5	1.3		Good
19	-16.0	14.2	364	0.31	2.7	0.9	NM+2.5	Good
26	-13.2	20.8	335	1.99	4.1	2.5		Good
Oct 3	15.3	2.1	326	2.28	4.3	2.8	FM+2	Moderate
10	15.7	8.2	208	0.99	1.5	1.1		Very Good
17	-17.9	14.8	403	0.23	3.0	1.0	NM+1.5	Good
24	-10.2	21.3	343	2.01	4.2	2.5		Good
31	17.4	2.7	360	2.20	4.6	2.8	FM+1	Moderate
Nov 7	12.8	8.8	181	1.07	1.2	1.1		Very Good
14	-19.4	15.3	445	0.30	3.4	1.1	NM	Poor
21	-7.3	21.9	295	1.97	3.7	2.5		Good
28	19.9	3.3	361	2.06	4.4	2.7	FM-1	Moderate
Dec 5	9.4	9.5	182	1.05	1.2	1.0		Very Good
12	20.6	15.9	511	0.52	4.2	1.6	NM-1.5	Moderate
19	-4.6	22.4	252	1.94	3.1	2.3		Good
26	20.4	3.8	363	1.92	4.3	2.6	FM-3	Moderate

TABLE B.

SKY TEMPERATURE ALONG MOON PATH

R.A. Hrs.	136 MHz	144 MHz	222 MHz	432 MHz	903 MHz	1296 MHz
0°	290°	252.8°	89.5°	18.1°	3.1°	1.3°
.5	310	270.3	95.6	19.4	3.3	1.5
1.0	325	283.3	100.3	20.3	3.5	1.5
1.5	340	296.4	104.9	21.2	3.6	1.5
2.0	370	322.6	114.1	23.1	3.9	1.7
2.5	410	357.4	126.5	25.6	4.4	1.8
3.0	420	366.2	129.6	26.2	4.5	1.9
3.5	410	357.4	126.5	25.6	4.4	1.8
4.0	420	366.2	129.6	26.2	4.5	1.9
4.5	470	409.8	145.0	29.3	5.0	2.1
5.0	540	470.8	166.6	33.7	5.7	2.4
5.5	595	518.7	183.6	37.1	6.3	2.7
6.0	570	496.9	175.8	35.6	6.1	2.5
6.5	475	414.1	146.5	29.7	5.1	2.1
7.0	420	366.2	129.6	26.2	4.5	1.9
7.5	350	305.1	108.0	21.8	3.7	1.6
8.0	250	218.0	77.1	15.6	2.7	1.1
8.5	220	191.8	67.9	13.7	2.3	1.0
9.0	200	174.4	61.7	12.5	2.1	0.8
9.5	210	183.1	64.8	13.1	2.2	0.9
10.0	215	187.4	66.3	13.4	2.3	1.0
10.5	230	200.5	71.0	14.4	2.4	1.0
11.0	240	209.2	74.0	15.0	2.6	1.0
11.5	270	235.4	83.3	16.9	2.9	1.2
12.0	300	261.5	92.6	18.7	3.2	1.3
12.5	360	313.9	111.1	22.5	3.8	1.6
13.0	360	313.9	111.1	22.5	3.8	1.6
13.5	370	322.6	114.1	23.1	3.9	1.7
14.0	400	348.7	123.4	25.0	4.3	1.8
14.5	440	504.7	135.7	27.5	4.7	2.0
15.0	480	418.5	148.1	30.0	5.1	2.1
16.0	595	518.7	183.6	37.1	6.3	2.7
16.5	795	693.1	245.3	49.6	8.5	3.6
17.0	1000	871.8	308.5	62.4	10.6	4.5
17.5	2200	1918.0	678.7	137.3	23.4	9.8
18.0	3700	3225.7	1141.5	231.0	39.4	16.5
18.5	2300	2005.2	709.6	143.6	24.5	10.3
19.0	1000	871.8	308.5	62.4	10.6	4.5
19.5	690	601.6	212.9	43.1	7.4	3.1
20.0	440	383.6	135.7	27.5	4.7	2.0
20.5	390	340.0	120.3	24.3	4.1	1.7
21.0	380	331.3	117.2	23.7	4.0	1.7
21.5	400	348.7	123.4	25.0	4.3	1.8
22.0	320	279.0	98.7	20.0	3.4	1.4
22.5	280	244.1	86.4	17.5	3.0	1.3
23.0	280	244.1	86.4	17.5	3.0	1.3
23.5	280	244.1	86.4	17.5	3.0	1.3
24.0	290	252.8	89.5	18.1	3.1	1.3
24.5	310	270.3	95.6	19.4	3.3	1.4

Figure 1 shows the 144 MHz sky noise (in dB) as a function of the moon position in right ascension in hours (24-0). As can be seen, minimum noise occurs when the RA of the moon is in the region of 8 to 12 hours. Two high peaks are noted, one of 3.8 dB at an RA of about 5.7 Hrs. and the other of about 11 dB around an RA of 17.9 hrs. The variation in earth-to-moon distance can introduce a variation of as much as about 2.4 dB in the path loss over a monthly lunar cycle with minimum being at perigee. For this reason the RA at which perigee occurs is important in determining the EME conditions. With best conditions being when perigee is near RA of 10 $\pm$2 hours. However, the RA for moon perigee is also a cyclical function with a period of about 9 years. Figure 1 (lower) shows the RA where perigee occurs (or occurred) over the 1988-96 time frame. As can be seen for 1992 and 1993 perigee is in the best possible region for a low DGRD factor. As expected the current EME conditions are great with many days during a month showing a DGRD of under 1.0 dB. This will continue during 1993 (see listings of Moondata) with several weekends being excellent. However, during 1994-95 conditions will deteriorate as perigee occurs in an increasingly noisy part of the sky. 1996 will also be poor but the downward trend will start to reverse during 1997-98.

Table B lists the effective sky temperature along the moonpath for right ascension (RA) in one-half hour increments. Data are listed for several VHF-UHF frequencies up through 1296. Data for 903 and 1296 shows very low noise temperature based on extrapolation from 136 and 400 MHz data. These numbers are slightly low since the minimum possible temperature is about 3°K and some correction is in order (next year) but these do show the trend.

Figure 2 lists some pertinent computer data used to calculate the W5LUU Moondata. The lines correspond to those in the 1986 WA1JXN moon tracking program for PC's but some are modified to either improve the accuracy or to better satisfy the current requirements. Receiving system (preamp noise + phasing harness loss + transmission line loss + local antenna noise) effective temperature is assumed to be 80°K for 144 MHz and 60°K for 432. The sky temperature data set is based on the mid-1992 moonpath and is slightly different from that used by WA1JXN but no major differences. This set should be good for the next several years.

Table C lists the sun position in RA for the mid-point of each month. While this does not have any direct bearing on EME it does provide useful information on where a particular RA is in relations to the sky. It is also useful, in conjunction with Table B, to determine sky background temperature behind the sun. This background can affect sun noise measurements by several dB at 144 MHz and has a noticeable effect even at 432. Unless corrected for background, for example, antennas checked for sun noise in late summer will show substantially less gain then when checked in June or December.

TABLE C.
SUN POSITION IN RIGHT ASCENSION (RA)

DATE	RA	DATE	RA
JAN 15	≈19.7 Hrs.	JULY 15	≈7.7 Hrs.
FEB 14	21.7	AUG 15	9.7
MAR 15	23.7	SEPT 15	11.7
APR 15	1.7	OCT 15	13.7
MAY 15	3.7	NOV 15	15.7
JUNE 15	5.7	DEC 15	17.7

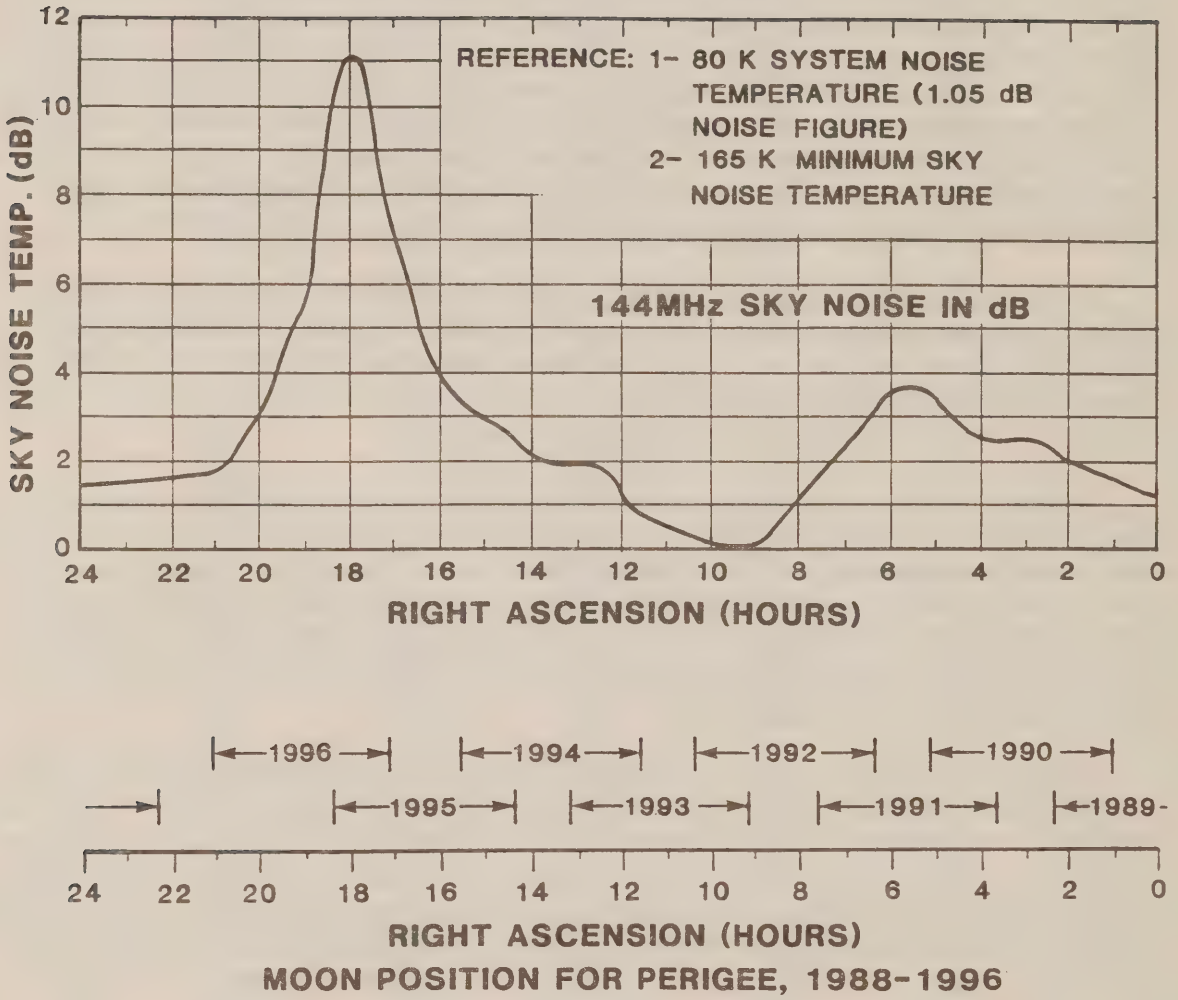


FIGURE 1 - MOONDATA VS. RIGHT ASCENSION

FIGURE 2 - COMPUTER DATA

THE FOLLOWING LISTS THE SYSTEM FACTORS, SKY NOISE DATA SET AND THE MODIFIED COMPUTER EQUATIONS USED TO GENERATE W5LUU MOONDATA. LISTED LINES ARE MODIFICATIONS OF CORRESPONDING LINES IN THE ORIGINAL MOON TRACKING PROGRAM FOR PC'S BY LANCE COLLISTER, WA1JXN, IN 1986.

```
360 '*****************************************************************
362 LET TEMRA=80       '144 MHZ RCVR SYSTEM NOISE TEMPERATURE, K
363 LET TEMRB=60       '432 MHZ RCVR SYSTEM NOISE TEMPERATURE, K

390 'FOLLOWING LISTS 136 AND 400 MHZ SKY TEMPERATURE DATA BASED ON MOON
391 'PATH FOR JUNE-JULY 1992  (REVISED JUNE 1992 BY W5LUU):

392 '********************LOAD SKY TEMPERATURE DATA*********************
396 LET RTEMA(I%)=RTEMA(I%)*.8718 '144 MHZ SKY TEMP IN DEGREES KELVIN
398 LET RTEMB(I%)=RTEMB(I%)*.8313 '432 MHZ SKY TEMP IN DEGREES KELVIN
400 NEXT I%
410 DATA 0,290,24,.5,310,24.5,1,325,25,1.5,340,25.5,2,370,27
420 DATA 2.5,410,29,3,420,30,3.5,410,28,4,420,30.5,4.5,470,34.5
430 DATA 5,540,37.5,5.5,595,45,6,570,44.5,6.5,475,37.5,7,420,32
440 DATA 7.5,350,25.5,8,250,19.5,8.5,220,17.5,9,200,15,9.5,210,15.5
450 DATA 10,215,16.5,10.5,230,17.5,11,240,18,11.5,270,19,12,300,22.5
460 DATA 12.5,360,27.5,13,360,27.5,13.5,370,25,14,400,27,14.5,440,30
470 DATA 15,480,32.5,15.5,520,35,16,595,39,16.5,795,45,17,1000,55
480 DATA 17.5,2200,110,18,3700,180,18.5,2300,160,19,1000,80,19.5,690,52
490 DATA 20,440,32,20.5,390,28.5,21,380,27.5,21.5,400,27.5,22,320,25
500 DATA 22.5,280,22,23,280,22.5,23.5,280,23,24,290,23.5,24.5,310,24.5

3015 '*******SUBROUTINE TO CALCULATE EME SIGNAL DEGRADATION FROM EARTH
            TO MOON DISTANCE AND BACKGROUND SKY TEMPERATURE**********
3016 LET DBR=40*FNL((RANGE-8110)/(348030!))'db degradation from actual
     earth-moon (surface to surface) distance compared to that at
     best possible perigee, i.e. 348030 km is minimum seperation, ever.
3020 FOR I%=2 TO 50
3025 IF H(I%)>RAH THEN 3050
3030 NEXT I%
3035 'Now for moon position calculate sky temp, KTEMPA for 144 & KTEMPB
3036 'for 432, & degradation factor, in dB, for this sky temp compared
3037 'to the lowest ever encountered along moon path: DBA is factor for
3038 '144 & DBB for 432. Note: Constants 174.36 and 12.47 in lines 3071
3039 'and 3072 are these lowest sky temperatures in degrees K. for 144
3040 'and 432,respectively, based on data set in lines 410-500. These
3041 'may need to be changed if different temperature data set is used.
3050  KTEMPA=INT((RTEMA(I%)-RTEMA(I%-1))/.5*(RAH-H(I%-1))+RTEMA(I%-1))
3070  KTEMPB=INT((RTEMB(I%)-RTEMB(I%-1))/.5*(RAH-H(I%-1))+RTEMB(I%-1))
3071 LET DBA=DBR+10*FNL((TEMRA+KTEMPA)/(TEMRA+174.36))'144 MHZ DB INDEX
3072 LET DBB=DBR+10*FNL((TEMRB+KTEMPB)/(TEMRB+12.47)) '432 MHZ DB INDEX

3800 'SUBROUTINE TO CALCULATE GEOCENTRIC MOON DISTANCE FOR GMT TIMES
3801 LET PRANGE=RANGE
3803 LET T8=(DATEJ-53997.5)+T    'TIME OF DAY.   NOTE: THIS EQUATION IS
         MODIFIED FROM ORIGINAL TO MOVE FROM MID-DAY REFERENCE TIME FOR
         EACH DAY (AS USED BY WA1JXN) TO 0000Z.
```

ARTCLE 16 - LEARNING TO USE AN AUDIO FILTER - THE SCAF

(READERS OF THE E.M.E. WILL BE THE FIRST TO SEE
ARTICLES 16, 17, 18, AND 19)

No, not you learning, this article is about me learning how to use an audio filter. The original title was going to be "I can't believe I was that stupid".
And don't anyone say "What do you mean, WAS ?" Anyway, here we go. There are three basic types of audio filters in use. The first type is called passive. A very nice unit was described in QEX, Dec., 1990, in "A High-Performance Narrow-Band 534 Hz. CW Filter Using Five 88 mh. Inductors". It features a 30/3 db. shape factor of 2.35, a center freq. of 534 Hz., a 3 db. bandwidth of 124 Hz., an insertion loss of 3.3 db., and a nominal impedance of 120 ohms.

The second type is obviously called an active (op amp) type, and there are many designs. A nice narrow unit appeared in "75 Hz. Wide Audio Filter", by W2OBJ in HAM RADIO, Jan., 1990. The trick is to build one so as to avoid excessive ringing.

One modern type of active filter, which is superior to analog filters, be they active or passive, is reffered to as a SCAF (switched capacitor audio filter). When I first read the article, "Super Scaf and Son - A Pair of Switched Capacitor Audio Filters", by WB4TLM and KB4KVE in QST. April, 1986, I could not believe my eyes !!! The MEASURED response curves shown were fantastic, as were the shape factors (almost as good as the Collins mechanical I.F. filters) !!! Needless to say, I bought one, and in kit form yet. After troubleshooting a couple of cold solder joints, the unit played, and it worked better than good!! With passbands narrower than 100 Hz., and extremely steep skirts, it was fascinating to hear signals pop in and out of the passband as you tuned the radio. The bandwidth is changed by moving upper or lower skirts, ie. cutoff frequencies, using thumbwheels. AND NO RINGING !!!

Now why was I stupid ? Well, over a period of time, I fell into the habit of leaving the HP-LP BCD code set at 03-10 (273 Hz.-1005 Hz.) for a 732 Hz. bandwidth on CW, and sometimes going to 03-06 (273 Hz.-601 Hz,) for a 328 Hz. bandwidth, or even lower to 03-04. As the LP approached 04, I usually switched the filter out, because it didn't sound too good. One day, I decided to calculate the bandwidths and center frequencies that result for various HP-LP BCD code combinations on the thumbwheels. What was happening is seen in table 1. As the bandwidth is made narrow by lowering LP, the center frequency changes !! This means the receiver needs to be retuned ! We get too soon old, and too late smart.

For a good description of what makes SCAF's work, see "Switched Capacitor Filters - An Emerging Technology for Amateur Radio Use", by W1JF and W3MT in QST, March, 1984. A review of several audio filters is presented in Audio-Filter Roundup in QST, Oct.,1991. Of particular interest is the MSC SMART filter. It is also a SCAF. On CW the bandwidth and center frequency can be set independently. In theory,this means that once an EME signal is tuned in, the filter center freq. can be adjusted for best response, and then the bandwidth adjusted for best S/N ratio. With the Super Scaf, bandwidth should be left as narrow as possible and not changed or the center frequency changes and the receiver then needs to be retuned. This back and forth retuning can cause one to build a "banana" array ! I have used both units, and both take getting used to. The Super Scaf has more audio, and I have seen used units for sale under $100.00 U.S.. The MSC SCAF (1304 Toney Dr., Huntsville, Alabama, 35802) sells for $195.00 U.S.

It is interesting to note that one of the latest Yaesu transceivers, the FT-990, has a SCAF (about time someone did it). The FT-990 review in QST, Nov., 1991, shows an MDS improvement of 10 dbm. for various I.F. bandwidths when adjusting the SCAF for minimum bandwidth. The article indicates that much of the improvement in minimum discernable signal resulted from elimination of I.F. noise.

But, how narrow a bandwidth can one use on EME ? And what about the filter of the third type ? Is the future here ? Not till ARTICLE - 17.

73,

K2GAL

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The European Moonbounce Edition is published by HB9CRQ. Previous articles have been published by the EME or the U.S. EME news published by KOIFL. Articles 13 and 14 were published in last year's Central States Conference Proceedings.

BCD CODE HP-LP	CUT-OFF FREQ (HZ) HP	LP	BANDWIDTH (HZ)	CENTER FREQ (Hz)
00-00	40	44	4	42
01-01	91	100	9	95
02-02	182	200	18	191
03-03	273	300	27	286
04-04	363	399	36	381
05-05	455	500	45	477
06-06	546	601	55	573
07-07	635	699	64	667
08-08	726	799	73	762
09-09	822	904	82	863
10-10	914	1005	91	959
00-00	40	44	4	42
00-01	40	100	60	70
00-02	40	200	160	120
00-03	40	300	260	170
00-04	40	399	359	219
00-05	40	500	460	270
00-06	40	601	561	320
00-07	40	699	659	369
00-08	40	799	759	419
00-09	40	904	864	472
00-10	40	1005	965	522
01-01	91	100	9	95
01-02	91	200	109	150
01-03	91	300	209	195
01-04	91	399	309	245
01-05	91	500	409	295
01-06	91	601	510	346
01-07	91	699	608	395
01-08	91	799	708	445
01-09	91	904	813	497
01-10	91	1005	914	548
02-02	182	200	18	191
02-03	182	300	118	241
02-04	182	399	217	290
02-05	182	500	318	**336**
02-06	182	601	419	391
02-07	182	699	517	435
02-08	182	799	617	490
02-09	182	904	722	543
02-10	182	1005	823	593
03-03	273	300	27	286
03-04	273	399	126	336
03-05	273	500	227	386
03-06	273	601	328	437
03-07	273	699	426	486
03-08	273	799	526	536
03-09	273	904	631	588
03-10	273	1005	732	639
03-15	273	1491	1218	882
03-20	273	1989	1716	1131
03-30	273	2983	2710	1628
04-04	363	399	36	381
04-05	363	500	137	431
04-06	363	601	238	482
04-07	363	699	336	531
04-08	363	799	436	581
04-09	363	904	541	633
04-10	363	1005	642	684
04-15	363	1491	1128	927
04-20	363	1989	1626	1676
04-30	363	2983	2620	1673
05-05	455	500	45	477
05-06	455	601	146	528
05-07	455	699	244	577
05-08	455	799	344	627
05-09	455	904	449	679
05-10	455	1005	550	730
05-15	455	1491	1036	973
05-20	455	1989	1534	1222
06-06	546	601	55	573
06-07	546	699	153	622

ARTICLE - 17 - THIS BAUD'S FOR YOU

In ARTICLE - 16 - Learning To Use An Audio Filter - The SCAF, I left you hanging out to dry with several unanswered questions. Let's look at the first one. How narrow a bandwidth can we use on EME CW ? Lest we forget - the reason for using a filter is to improve the S/N so that we hear something other than noise ! There is a very real problem in using very narrow bandwidths. To effectively use very narrow BW's the BW (Hz.) must be matched to the signalling rate (BAUDS). The LOW-FERS on the 1750 meter band use bandwidths down to 1/60 Hz. (Gulp, and Wow !), with super slow CW of 1/10 to 1/60 BAUDS (that's 7.2 to 1.2 WORDS-PER-HOUR !!!) Max Carter, in "Super Narrow Band Techniques Equalize Power Inequity on 1750 Meters", Nov. 1990 issue of "Communications Quarterly", (the real HAM RADIO magazine replacement - published by CQ magazine), points out that the matching should be 1 Hz. per baud (that's BAUD, not BUD like in beer !) and that the narrowest bandwidth for AURAL CW LowFer DX work is about 10 Hz. (this would mean CW somewhere around 3 WPM for AURAL detection, and about 10 WPM for MACHINE detection).

The duration of a data bit in an asynchronous character is by definition, the inverse of the the transmission SPEED in BAUDS. But of course you already knew that ! The relationship between Bauds, Bandwidth, CW-WPM, and the keying shape factor is covered in chapters 9 and 19 of "The 1990 ARRL Handbook For The Radio Amateur". Using the standard word "PARIS", the relationship between CW-WPM, and Bauds is given as;

WPM x 0.83 = BAUDS or BAUDS = WPM / 1.2

A good rule of thumb equation relating BW and CW-WPM is also given,

Bandwidth (Hz.) = WPM x K,

where K depends on keying wave shape and a K = 4 is used for modern transceivers.

So, a 30 WPM CW signal takes up about 120Hz., and obviously the receive filter should be near that wide. Some confusion might arise on seeing the 1 to 1 relationship by Carter. This is resolved by AA4AB (see Tech Correspondence - "The CW Demodulator Revisited", in QST, July, 1985), by using K = 1 for machine recognition of CW. For aural copy, a K of 3 is minimum. As he states, it is not unreasonable to expect automatic copy at 60 WPM using a 75 Hz. filter. (His preceding statement of a theoretical max speed that can be used with a 75 Hz. filter of 90 WPM appears to be in error, and probably should be 75 WPM. Evidently the 1.2 Bauds /WPM factor got in there somehow). The K factor is also well covered in chapter 9 or the ARRL handbook. I find that for aural EME CW, a K of 4 seems to fit the bill, which makes a bandwidth of about 100 Hz. the limit for aural detection. And there you have my answer to that first question, ALMOST !

I said that the aural detection bandwidth limit for EME is "ABOUT 100 Hz.", because;

1.) It takes practise to use a 100 Hz. bandwidth.

2.) It takes a LOT of practise to use a smaller bandwidth.

3.) It requires excellent STABILITY for both the transmitted signal and the RX. If a signal drifts 1 or 2 KiloHz., using a 50 Hz. bandwidth requires a lot of tuning. The best VHF XCVRS tune 10 Hz. per step using RIT, while the best HF rigs tune 1 Hz. per step ! With fading, etc., it takes a lot of work to find a signal when using very narrow bandwidths. The small station must have lots of patience.

4.) A lot of small stations make the mistake of sending fast, because the big station on the other end is so strong !

5.) I WILL TELL YOU IN A FUTURE ARTICLE HOW YOU CAN USE VERY NARROW BANDWIDTHS (DOWN TO 10 Hz. OR SO) ON EME !!!!! AND YES, YOU WILL HEAR THE WEAK SIGNALS BETTER !!

Meanwhile, in "Coherent CW - The Concept", in QST, May, 1981, W6NEY indicates that at 12 WPM a CW signal occupies about 10 Hz. With a 500

Hz. filter, this means one hears the 10 Hz. wide signal, AND 490 Hz. OF NOISE AND QRM !!!! This article, along with "Coherent CW - The Practical Aspects", in Qst, June, 1981, by W6NEY, and the Max Carter article cover the super-narrow filters used in Coherent CW. Max Carter show that to achieve a 1/10 or 1/60 Hz. non-ringing filter, three techniques are used in Coherent CW; Fully synchronous mod/demod, Binary Phase Shift Keying, and the Integrate-Sample-Reset (Integrate and Dump) Filter.

Starting with a 10 Baud (that's how many WPM ? - that's right - 12), 10 Hz.bandwidth aural CW system, and going to a super-narrow system at 1/60 Baud (that's 0.02 WPM, or 1.2 Words-Per-Hour), gives a 36.8 db. improvement in S/N !! Synchronous detection gives 3 db. over a diode detector, BPSK gives 6 db., and BANDWIDTH REDUCTION - THE REAL WINNER - gives 27.8 db. !!!! So, TO SIGNIFICANTLY IMPROVE S/N (of course you have already maxed out on antenna gain, and other parameters the EME LINK EQUATION showed you in ARTICLE - 7 - The Missing Link) NARROWER BANDWIDTHS ARE REQUIRED, and super-narrow bandwidths REQUIRE MUCH SLOWER CW (WPH). THIS IS A FACT OF LIFE - LEARN IT WELL !!!!

Significant S/N improvement can be had by using narrow bandwidths down to 10 Hz. with reasonable WPM. Obtaining narrow bandwidths at I.F. frequencies is covered quite well by DK1AG in "The Optimum I.F. Selectivity for Coherent Telegraphy (CCW)", in the 3/82 issue of VHF Communications. The main selectivity ie. less than 10 Hz. bandwidth can presently only be obtained at the A.F. level. To use filter bamdwidths below 100 Hz., machine detection of CW signals should be employed to take advantage of the higher WPM with a K = 1. To accomplish this, a CW demodulator is required. One such unit, described by AA4AB in " A High Performance CW Demodulator", QST, April, 1985, allows automatic CW reception using any computer, and CW copying software.Some experimentation with the AGC-filter time constant will probably be required, since the unit described does not adapt too well to large decreases in signal level. Additional improvements with respect to QRM

and QRN can be realized using audio rectification feeding a differential amplifier to control the gain of a voltage controlled amplifier. (See "Concept and Construction of a CW Filter and Enhancer", by N3AXN in QST, April 1982.) For additional circuitry, that eliminates noise bursts shorter than 8 milliseconds, see "The CW Filter-Limiter", by WA2QIQ, in QST, Jan., 1979. And while you are at it, be sure to read "Digitized Speech-Part 1", by WA4SFP in the same issue.

Now what's the filter of the third type ? Is the future really here ?

73,

K2GAL

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ARTICLE - 20 - ANTENNA POWER COMBINER LOSS

Yes, there is a quiz, and here it is; Power P, is split by a two way Tee power divider, resulting in P/2 being delivered to two lines, each having a 3 db. loss. The output of each line is then = P/4. The total power out of the two lines is = P/4 + P/4 = P/2. This represents a 3 db. loss. Since total line loss is 3 db. + 3 db. = 6 db., what happened to the other 3 db.? Ans. at end.

In order to increase transmit gain and the receive S/N ratio, the number of antennas is usually increased. The multiple antenna array requires a power divider/combiner. Symmetrical power dividers, such as the branch waveguide coupler, the short-slot hybrid, and the contra-directional coupler, provide phase quadrature outputs to the antennas with isolation between them. The hybrid ring directional coupler, the magic-T, and the N-way power dividers provide in-phase, or out-of-phase outputs.(1) A branch-line hybrid,(2), or coaxial hybrid ring,(3), (commonly called a "rat-race") can be used to combine two amplifiers in parallel with isolation between them.

To feed multiple antennas, most radio amateurs use the simple Tee power divider, or it's expanded version, the N-way Tee. The main reasons for using a Tee is that it provides in-phase outputs, unfortunately with low isolation, and is easy to build.

Two types of Tee power dividers are in common use, the single Q-section, and the multiple Q-section, where the Q-section is the impedance transforming section. Fig.1 shows these for two and four-way dividers.

On transmit, for two antennas (see Fig.1b), the transmitter power is equal to E-squared/50 at the junction. It "sees" two antenna ports in parallel and since each 50 ohm antenna impedance is transformed to 100

ohms with the 75 ohm quarter-wave Q-sections, the power for each antenna line is E-squared/100. Quite obviously, the transmitter power is divided in half (-3db.) for each antenna,ie., E-squared/50 = E-squared/100 + E-squared/100. The same half-power division is obtained for the single Q-section Tee (Fig.1a). Similarly, for a four-way divider, the transmitted power is evenly divided (ie. P/4 or -6 db.) for each antenna (single or multiple Q-section). No problem on transmit, but how about on receive, when the divider becomes an antenna power combiner ?

There are several ways to determine combiner receive gain. The first uses the same simple power/impedance analysis as we just did on transmit. Each antenna feed provides power P1,P2,P3,....Pn,to the junction. At this point, the power from each antenna is divided according to the impedance ratio, between the receive line and the other antenna lines. With perfect antennas, lines, etc., the divided power going to the other antennas is obviously re-radiated (we will assume this is the situation). The receive power gain is then calculated by dividing the power from a single antenna in the receive line,Prx, by the available power from a single antenna,Pn, and multiplying by n, the number of antennas. For simplicity, each antenna is assumed to provide the same power, ie., P1 = P2 = P3 =.....Pn. Please note that the receive combiner gain is not the directivity gain due to multiple antennas, although it is usually assumed the two are equal (ie. there is no combiner loss, a bad assumption, as we shall see).

Let us now go through some examples of combiner power gain calculations.

Case 1 - Two antennas - single Q-section

At the junction, the power from antenna 1,

P1 = E-sq./25 + E-sq./50 = P(rx) + P(line 2)

Similarly, for the power from antenna 2,

P2 = E-sq./25 + E-sq./50 = P(rx) + P(line 1).

The power to the receiver from antenna 1 is,

P(rx) = P1 - P(line 2) = (E-sq./25 +E-sq./50) - E-sq./50

= E-sq./25

The portion of antenna 1 power received is,

P(rx)/P1 = (E-sq./25) / (E-sq./25 + E-sq./50)

= (E-sq./25) / 3 E-sq./50

= 2/3

Total power received is,

n[P(rx)/P1] = 2 x 2/3 = 4/3 , the total power gain from two antennas. So the power gain is 1.33 or 1.24 db. rather than the expected 3 db.!

Case 2 - Four antennas - single Q-section

At the junction,

P1 = E-sq./(50/4) + E-sq./50 + E-sq./50 + E-sq./50

= P(rx) + P(line 2) + P(line 3) + P(line 4)

The power to the receiver from antenna 1 is,

P(rx) = P1 - [P(line 2) + P(line 3) + P(line 4)]

= E-sq./(50/4) + 3 E-sq./50 - 3 E-sq./50

= 4 E-sq./50

The portion of antenna 1 power received is,

P(rx)/P1 = (4 E-sq./50) / (4 E-sq./50 + 3 E-sq./50)

= 4/7

Total power received is,

n[P(rx)/P1] = 4 x 4/7 = 16/7 , the total power gain from four antennas. In this case, the power gain is 2.28 or 3.57 db. rather than the expected 6 db.

The same results are obtained for either single or multiple Q-sections.The same approach was used for 8 and 16 antennas, and the results are presented in table 1, and plotted in Fig.2. Please note that

for the expected antenna gains given, it is assumed that the antennas are spaced properly, so that the antenna area is effectively doubled each time the number of antennas is doubled, and a 3 db. gain increase occurs. The results show the following;

1.) The simple Tee divides power evenly on transmit, however on receive the combiner gain is less than what one expects from the increase in directivity due to multiple antennas.

2.) A two-antenna combiner takes the biggest hit, with less additional loss (incremental loss) occuring as the number of antennas is increased.

Now, what are the other ways to determine combiner gain ? The second way is a precise mathematical computation and utilizes scattering matrices (4). The equivalent circuit for a two-way combiner is given in Fig.3. The use of the second method is left to the reader.

There are two ways to determine combiner gain through measurements. The first of these is to determine the loss (negative gain) from one antenna port to the receive line, with the other antenna ports terminated properly, and is a good exercise for someone with good lab equipment. For equipment, an HP-608 signal generator, and an HP-415 SWR meter and detector with at least 10 db. of padding would be required. For a two-way combiner, considerable care is required, since the values are low, and of the same magnitude as expected errors.

The second way to measure the gain is shown in Fig.4. Here the power transmitted from the multiple antenna array is recorded at the reference antenna receive site. The transmitter and receiver are then switched around, and the detected power from the multiple antenna array and combiner is noted. Unfotunately this method is most difficult to use due to reflections and stability problems.

References:

(1) "Split-Tee Power Divider", by L.T. Farad, and R. L. Moynihan, IEEE Transactions on M.T.& T., Jan. 1965

(2) "The Branch Line Hybrid; Part 1", by WA2EWJ, Ham Radio,April, 1984
(3) "Control Your Power Split Using a Hybrid Rat Race" by C.Y.Pon, Microwaves, April,1970.
(4) "Matrix Theory For Electrical Engineers", by A.M. Tropper.

TABLE 1. N-Way Tee Power Combiner Gain

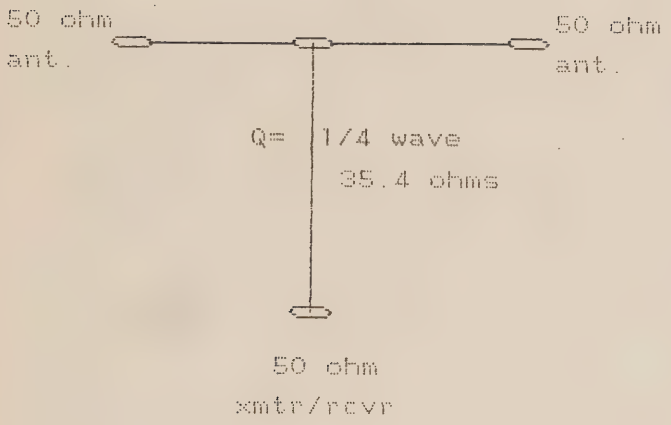
No. of Ant. n	Expected Ant.Gain db.	Actual Combiner Gain-db.	Incremental Gain db.	Loss (2)-(3) db.	Incremental Loss db.
2	3	1.24	1.24	1.76	1.76
4	6	3.57	2.33	2.43	0.67
8	9	6.3	2.73	2.7	0.27
16	12	9.15	2.85	2.85	0.15

73,

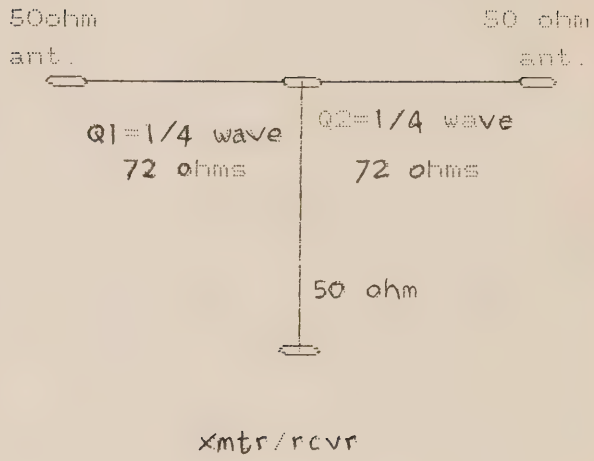
K2GAL

[Note:This article may be reprinted or quoted promiscuously, provided proper credit is given.]

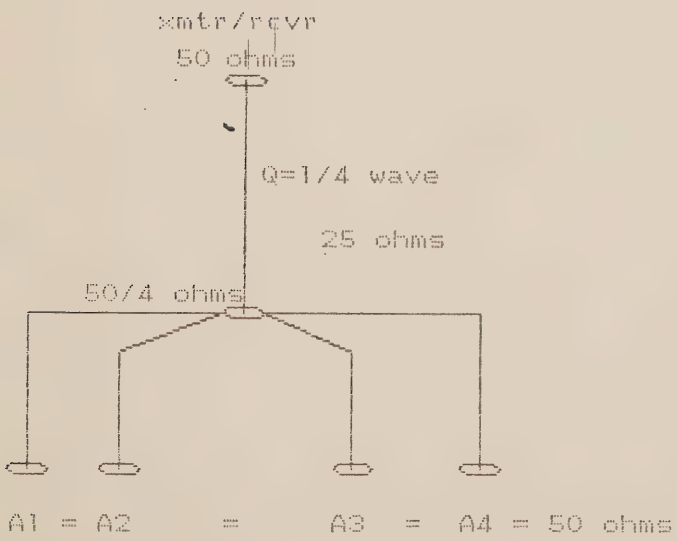
Ans. to quiz: The two lines are in parallel, and not in series, therefore total power loss is equal to the loss of one line, regardless of the number of lines. EMErs take note. Did you get a passing grade ?



1(a) single Q

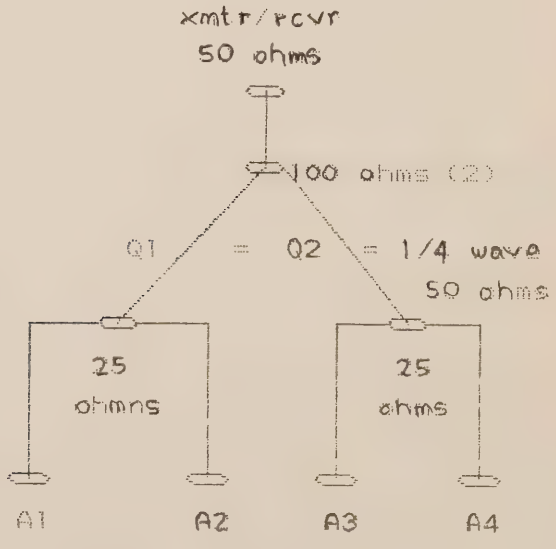


1(b) two Q



(3, 4, and 5 Q
not shown)

1(c) single Q



1(d) Two Q

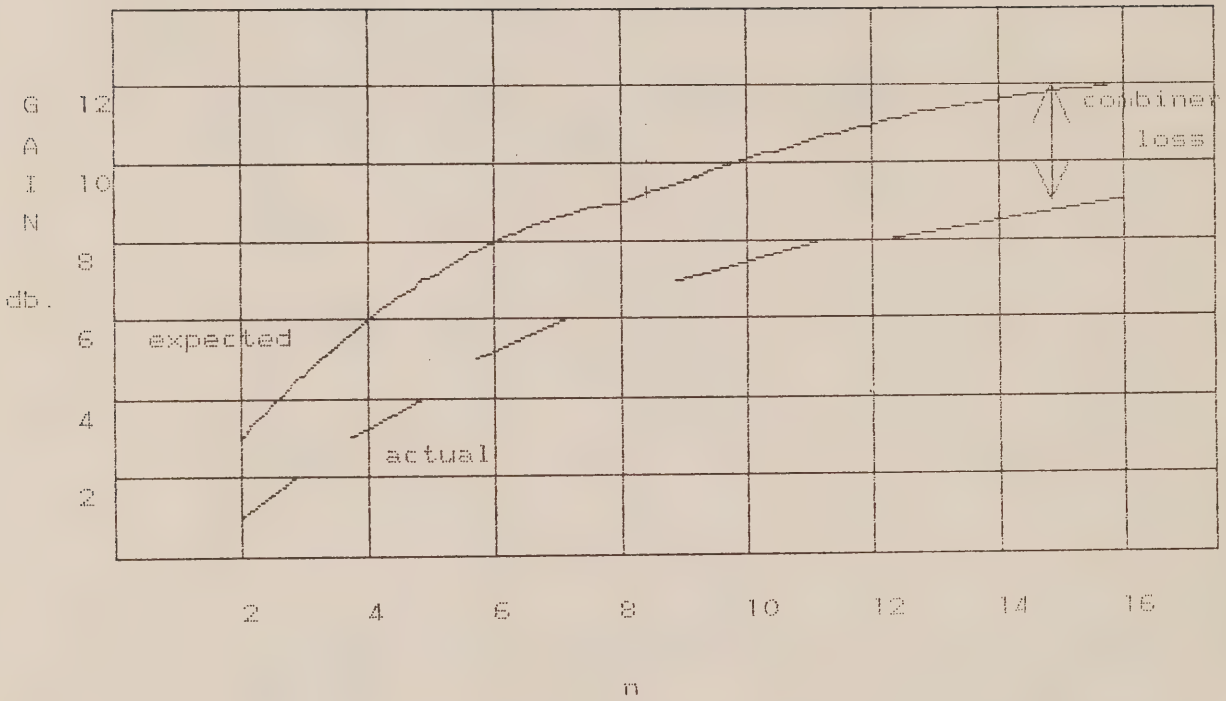


Fig.2 N-way Tee Power Combiner Gain (see text)

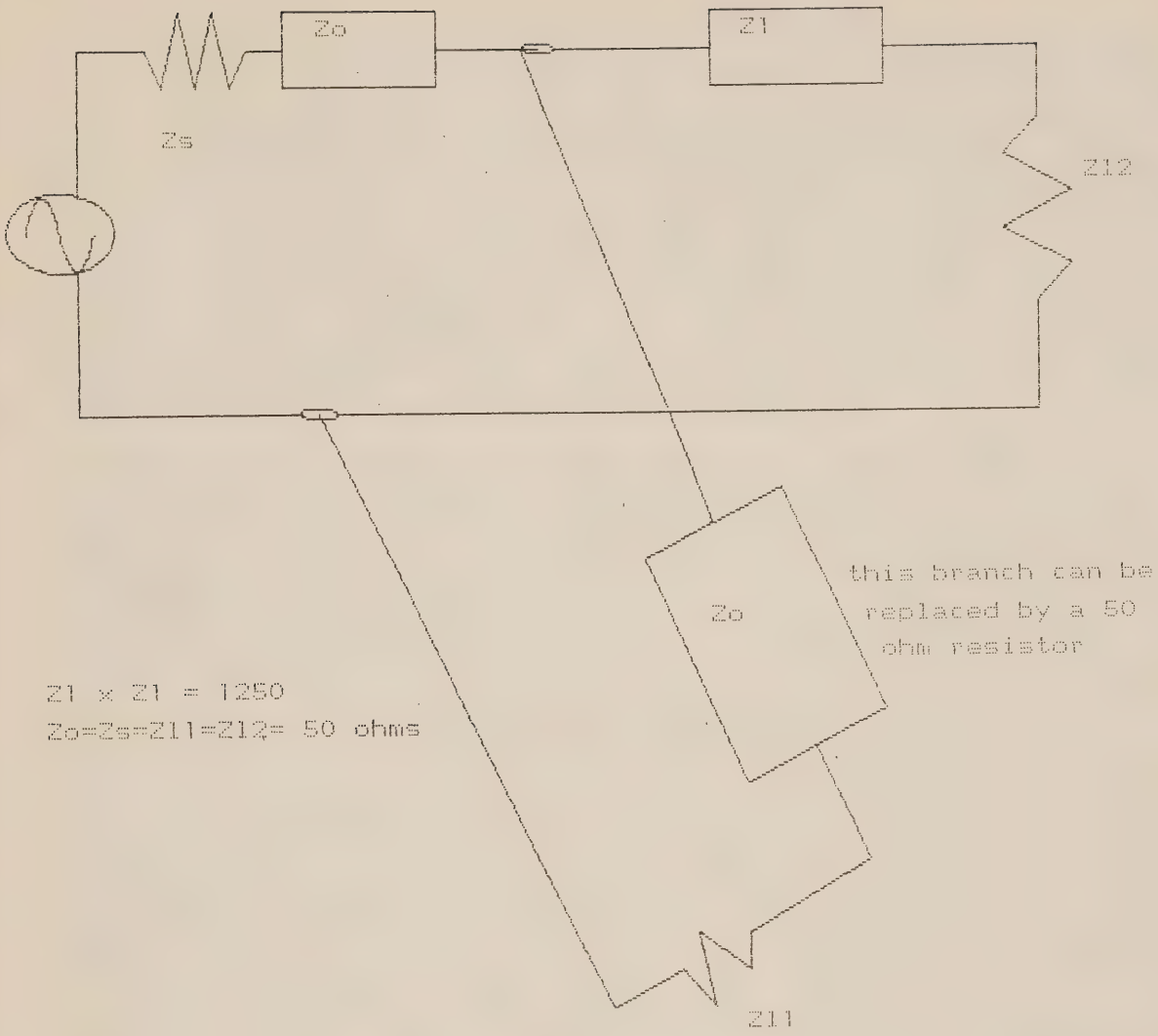
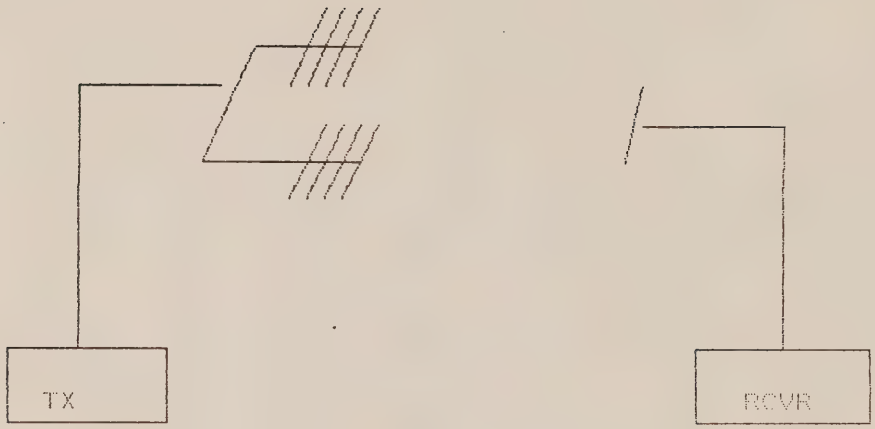


Fig.3 Equivalent Circuit for Two-Way Tee Power Combiner



RX power is noted, then TX and RCVR are interchanged, and power noted again.

Fig.4 Measuring Combiner gain the hard way.

QRP EME ON 144 MHZ: HOW AND WHY

by Ray Soifer, W2RS

In my 37 years as a radio amateur, I've always been contrary enough to want to try things simply because they hadn't been done before. So, in 1985, when I saw an article in the 2 Meter EME Bulletin by Dave Blaschke, W5UN, about his brand-new Mighty Big Antenna with 32 4.7-wavelength Yagis, and how he hoped it might be possible, under ideal conditions, for him to work someone with just a single Yagi and as little as 300-400 watts, I couldn't resist picking up the phone, introducing myself and asking Dave how he'd like to try someone with a B1016 and a 32-19 Boomer. We made it on the third attempt, on November 17, 1985. Over the next year or so, I worked Dave several more times, including once on random (i.e., without a prearranged schedule). A little over a year later, I worked Gary, KB8RQ, to earn Worked All 32-Antenna Stations on 144 MHz EME.

What should I try next? I asked that question of Lionel, VE7BQH, on the 2-Meter EME Net soon after working Gary, and before Lionel could answer, there was W5UN breaking in and saying "Lionel, you've got great ears, why don't you try to work him yourself?" Lionel's then 224-element collinear array had about 6 dB less forward gain than W5UN's system, but Lionel had one very important advantage: he could rotate his antenna in polarity as well as azimuth and elevation, which would help greatly to cope with the Faraday rotation which is a major problem for the vast majority of 2-meter EMEers with fixed-polarity horizontal arrays. Working VE7BQH took more like 13 tries than three, but we finally made it in March of 1987. That contact, as much as my first with W5UN, really opened my eyes to what might be possible for a station such as mine on 2-meter EME.

QRP EME turns out to be an excellent way to learn about EME propagation and to develop operating techniques with which to make the best use of the knowledge gained. It often comes as a surprise to those who have never actually tried EME for themselves -- and even to some who have -- that it is frequently possible to complete two-way contacts even when the standard link equations contained in handbooks and computer programs predict that signals will be far below the noise, and that EME schedules sometimes fail even when the predicted signal-to-noise ratio is positive. In fact, nearly all of the EME contacts I have completed had predicted S/N ratios that were negative. In my average contact so far, the predicted S/N ratio for my signal at the other station's receiver was -4 dB in a 100 Hz bandwidth. I've completed 20 QSOs where the predicted signal deficit was 8 dB or more and three where it was 15 dB or more. In such cases, you either make good use of favorable propagation or you simply don't make contact at all.

By now, it has become nothing unusual for someone to complete EME contacts on 2 meters with 100-150 watts and a single Yagi. It has been done hundreds of times, often by people who've read some of the articles written by W5UN and W2RS. That makes me very happy indeed. In fact, the state of the 2-meter EME art has improved by a full order of magnitude since that night in 1985 when I worked W5UN for the first time. On January 21, 1992, Arne, CO2KK worked Gary, KB8RQ using 22 watts and a 10-element array; Arne's effective isotropic radiated power (eirp) was only about 450 W (26.5 dBW), more than 10 dB down from the 5 kW eirp (37.1 dBW) I had used to work W5UN in 1985. If my station is QRP, then CO2KK must be QRPp!

As of the end of April when this paper was written, I had made 67 two-way EME QSOs with 26 different stations, and every time I work a new one it still sets a record of sorts for my power and antenna class. Most of those worked were not "superstations" such as W5UN or KB8RQ: as of the

end of April when this paper was written, I have worked eight stations with eight long Yagis or the equivalent in forward gain, three six-Yagi stations and seven four-Yagi stations. The smallest of those, WB2OYC, was using four 2.1-wavelength Jr. Boomers, whose combined forward gain is less than many two-Yagi stations currently active and nearly 11 dB down from W5UN's first 32-Yagi array. I have even worked W5UN twice on SSB, and heard and taped my own brief, fragmentary lunar echoes -- that's about 17 dB down from W5UN! In the 1990 ARRL EME Contest, I worked four stations, and six worked me in the 1991 Contest including two (KI3W and AA4FQ) with four Yagis each. And, as you know, Dave's 1985 dream of 2-meter DXCC is now a reality, thanks in part to the many small stations which have gotten "on the moon" from new countries and expeditions.

I'd like to spend the remainder of this paper sharing what we've learned over the past seven years about propagation modes useful for working small stations on 2-meter EME and the operating techniques we have evolved to take advantage of them. Some of these modes and techniques are quite different from the prevailing practice at 70 cm and higher frequencies, and even from what one might do at 2 meters when working larger stations. In so doing, may I gratefully acknowledge that the "we" who have evolved these techniques includes all of the outstanding operators with whom I have completed and who, by pulling my weak Os, ROs and Rs out of the noise, did at least 90% of the work. I hope they had as much fun working me as I did them; their calls are listed in Table 1 along with the arrays they used to work me.

Ground Reflection Gain

All of my EME QSOs have involved ground reflection gain, as my own antenna is not elevated and the moon was always between 3 and 12 degrees above my horizon. The position of my antenna produces a ground reflection lobe centered at about 3.5 degrees elevation with approximately 5 dB gain and a second lobe at about 10.5 degrees with around 3 dB gain. Were the earth a perfect reflector, ground gain of 6 dB would be theoretically possible, but I am not so lucky. At 144 MHz, ground reflection gain decreases rapidly as the radiation angle is increased beyond about 12 degrees or so, with the specifics depending upon terrain and the reflection characteristics of the earth.

While ground gain appears at all frequencies, it is often considerably more useful for practical EME communication at 144 MHz than at 432 MHz and higher bands because of differences in noise level. At 2m, the levels of sky noise encountered in EME work often are not far removed from the 290 K black body radiation of the earth itself; the mean sky noise observed during my own EME QSOs was 289 K. Contrast this with the typical sky noise values of 20 K or less at 432 MHz. Especially for those living in quiet locations or operating at times when man-made noise is not likely to be present in large quantities, the price paid in reception capability for the 3-5 dB of gain provided by ground reflection is much smaller at 144 MHz than at higher frequencies.

For those with stations capable of at least 10 kW (40 dBW) eirp, I recommend installing an elevation rotator. In addition to greatly expanding the amount of available moon time compared to a moonrise-moonset station, elevating the antenna substantially reduces the reception of man-made noise and permits taking advantage of times when sky noise is well below 290 K. On the other hand, for the QRP single-Yagi station with less than 10 kW eirp, the availability of ground-reflection gain at elevation angles of 12 degrees or less generally means the difference between success and failure.

Mutual Ground Gain

As discussed in my articles in QST and Radio Communication [1], mutual ground gain can occur when the moon is near the horizons of both stations at the same time. Since ground gain at one end of the path is capable of contributing 3-5 dB of additional signal strength, it is easy to see how desirable it would be to double this contribution by arranging schedules, if possible, at times when mutual ground gain is likely to be present. Theoretically, of course, a perfectly reflecting Earth would result in up to 6 dB of ground gain each way and a total of 12 dB in a mutual ground gain situation. However, a perfectly reflecting Earth rarely occurs in practice, while antenna patterns often limit ground gain as well.

As noted above, all of my EME QSOs have involved ground-reflection gain at least at one end of the path. During 16 of these QSOs and, of course, both times when echoes were heard, lunar elevation at both stations was such that mutual ground gain was likely to be present. These included all but two of my 13 completions with seven stations in the four-antenna class [those two will be discussed later in this paper]; one of these mutual ground gain QSOs was with Paul, WB2OYC, whose forward gain with four CushCraft Jr. Boomers was about the same as that of a two-antenna station with 17LBX or 2M-5WL Yagis. Using mutual ground gain, I have also worked Peter, SM2CEW, a 6-Yagi station in Lulea, Sweden, near the Arctic Circle, and the record-breaking contact between KB8RQ and CO2KK also took place by means of mutual ground gain despite those two stations being approximately 1,200 miles apart. These two examples demonstrate that stations need not always be located near each other geographically for mutual ground gain to be present.

However, the additional signal strength provided by mutual ground gain brings with it problems of its own. Most notably, the low elevation angles required at both stations often result in increased noise. While there is usually little that can be done about the noise itself, the right choice of schedule times may help to compensate for it. In particular, when the antenna will be pointed near the horizon, there is little reason to choose times when the sky noise will be less than about 300 K, since in such cases the noise floor is likely to be limited by Earth noise of at least that much. For the 18 cases of mutual ground gain in my log (the 16 QSOs and the two echoes), the mean sky noise was 320 K, while for the 51 QSOs without mutual ground gain, it was 277 K.

For mutual ground gain schedules, minimizing the range factor by choosing times close to lunar perigee is often more important than the amount of sky noise, as long as the latter is not higher than the Earth noise. In my log, the mean range factor for the cases of mutual ground gain was 0.5 dB, while for the other QSOs it was 0.9 dB. While the average degradation (DGRD) for the mutual ground gain cases was the same as that for the other QSOs (2.5 dB), its composition was thus very much different. Evidently, mutual ground gain schedules can tolerate more sky noise but less path loss than can 2-meter EME schedules in general.

Analysis of the conditions prevailing on December 29, 1990, when I was able to tape-record my lunar echoes, showed that the moon was nearly at perigee (0 dB range factor) while the sky noise was 373 K, a level comparable to or slightly above the local Earth noise. Under these conditions, the predicted S/N ratio in my receiver (excluding ground gain and libration enhancement) was -17.4 dB in a 100 Hz bandwidth. With the moon in the major ground-reflection lobe of my antenna, I estimate that a total of 10 dB of ground gain was present, 5 dB transmitting and 5 dB receiving. A strong libration peak (see below) of about 0.6 second

duration resulted in a clearly audible signal making it onto the tape. Conditions on November 4, 1990, when lunar echoes were heard for the first time but a cassette failure prevented their being recorded, were virtually identical.

A low elevation angle results in the signal spending more of its trip traversing the ionosphere than at higher angles, increasing the amount of Faraday rotation one can expect. According to one source [2], the wavefront of a 2-meter signal passing through the ionosphere (one way) will typically rotate 1.4 times (about 500 deg) at the zenith but 4.4 times (about 1,600 deg) at the horizon. These figures vary considerably with ionospheric density, as well as the moon's relative motion in the sky, but it is clear that with the moon near the horizon, the polarity of the incoming wave will change more rapidly and more unpredictably due to Faraday effects than if the moon were high in the sky. So, too, will the polarity of the outgoing wave.

When trying for mutual ground gain, this rapidly changing Faraday rotation will be present at both ends of the path, often resulting in very short windows of usable signal in which to pass the information needed for a complete QSO. In most of the one-hour mutual ground gain schedules that I have run, such windows have lasted less than five minutes when they have been present at all. My experience has been that one-minute transmitting sequences are more effective in this situation than the standard two-minute sequences. However, I continue to use two-minute sequences for schedules when mutual ground gain is not likely to be present.

Libration Enhancement

The moon's wobbling motion, or libration, gives rise to multipath interference effects on reflected signals. Short-lived enhancements of up to about 10 dB above normal signal levels may be produced in this way, as are deep fades. Claus Neie, DL7QY, estimates that enhancements of 7 dB and fades of 17 dB from the mean strength of reflected signals occur 1% of the time, while enhancements of 4.5 dB and fades of 7.5 dB occur 10% of the time [3].

The fading rate is directly proportional to the operating frequency, hence the duration of signal enhancements is inversely proportional to frequency. Because so much of the original pioneering of EME was done at 1296 and 432 MHz, where libration enhancements typically last less than 0.4 sec and less than about 1 sec, respectively, led to a widespread belief that libration was nothing but a nuisance: at these frequencies, one could hear the enhanced signals as well as the fades, but because the fading rate was faster than the CW keying rate, the libration-enhanced signals were rendered uncopiable.

At 144 MHz, the situation is very different. Libration enhancements of 3-4 sec are quite common, and this can be more than enough time to pass meaningful information. At 18 WPM, for example, my call sign takes less than 3 sec to send, while the sequence "RO" takes about 1.5 sec.

Partly as a way of coping with libration fading, EMEers at 432 MHz and above tend to utilize very slow CW speeds, typically around 10-12 WPM. However, the duration of signal enhancements at 144 MHz makes faster speeds than this extremely desirable. In view of the above examples, I normally set my keyer for 18 WPM, and most other experienced 144 MHz operators have also learned to use speeds of 15-20 WPM in preference to the slower speeds still common at the higher frequencies. If the proper CW speeds are employed, libration fading can be a powerful aid to completion of 144 MHz

EME QSOs.

Libration enhancement was responsible for my being able to work Don, W7VXW, on November 29, 1991; his four 2M-5WL Yagis make W7VXW the smallest station I have worked so far without mutual ground gain. There was no ground gain at W7VXW as Don's lunar elevation exceeded 30 deg. With sky noise of 209 K, the theoretical SNR (excluding ground gain) was -9.2 dB and the lunar elevation at W2RS produced ground gain of about 5 dB. Short libration peaks were evident at both ends; W7VXW reported that the only signals he heard from me at all were on these brief enhancements of 5 sec or less.

Ionospheric Scintillation

On November 24, 1991, five days before working W7VXW, I worked Jeff, AA4FQ, a station with four 5.1-element Yagis. Under the prevailing conditions at that time, with path loss of 0.2 dB over perigee and sky noise of 409 K, the theoretical S/N ratio for my signal at AA4FQ was about -10.6 dB in a 100 Hz bandwidth, excluding ground gain.

All of my previous completions with four-antenna stations had made use of mutual ground gain. This time, however, the lunar elevation angle at AA4FQ was between 17 and 20 deg during our schedule; not much ground gain there, if any. At W2RS, the moon was between 9 and 11 deg, falling into a lobe of my vertical pattern that typically produces ground gain of about 3 dB. That still left approximately 7.6 dB of signal to be made up somehow, if a contact was to be completed. Libration enhancement does not appear to have been involved. At two meters, the duration of libration peaks rarely exceeds 4-5 seconds and is generally shorter. During this contact, strong lunar echoes were observed lasting 30 seconds to a minute or more.

These long-lasting echoes may have resulted from ionospheric scintillation. According to Lawrence [4], when a radio wave from a distant source (e.g., the moon) reaches the ionosphere, the phase surface of the wave is distorted by irregular patches of varying refractive index. These patches are constantly moving, giving rise to interference effects which, in turn, result in the fading known as "amplitude scintillation." Lawrence compares this scintillation to the apparent twinkling of optical stars, except that the "twinkling" of radio waves occurs in the ionosphere and not the troposphere as with light waves.

Davies [5] reports that the rate of scintillation observed in the case of radio stars varies between 10 fades per minute (i.e., one every six seconds) to around one fade every 10 minutes. The scintillation rate appears to be independent of frequency above about 30 MHz. Davies comments further that when [low Earth orbit] satellites are used as sources instead of stars, the scintillation rate depends partly on the height and speed of the satellite and is generally much faster, typically around 10 fades per second. Owing to the moon's distance and low angular velocity relative to the Earth, the scintillations experienced in EME resemble those of radio stars rather than low Earth orbit satellites. The amplitude of fading falls off with frequency; it is much smaller at 432 MHz than at 144 MHz.

Like Faraday rotation, scintillations are non-reciprocal. Most of the scintillation effect occurs on the moon-to-earth leg of the journey, and the signals reaching each station will have passed through different regions of the ionosphere. Scintillation also increases as the lunar elevation angle decreases.

Davies notes that during sunspot minima and periods of low solar flux,

scintillations occur more often at night than in the daytime. However, when solar activity is high, the distinction between day and night tends to disappear. Diurnal variations are also less significant at high latitudes. The seasonal variations seem to be more complex: in temperate latitudes, scintillations are reported to be more common near the spring and fall equinoxes; however, near the equator their occurrence peaks in the summer while some stations at high latitudes report a peak during the winter.

Apart from the correlations mentioned above, I'm afraid there does not seem to be a simple method of scheduling to take advantage of scintillation, at least not one that has yet been developed. The completion with Jeff has made me more aware of its existence, and convinces me more than ever that there is still much we do not fully understand about 2-meter EME that makes it possible to do things we had not thought we could.

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2. M. Davidoff, K2UBC, The Satellite Experimenter's Handbook, 2d ed., ARRL, 1990, pp. 13-7 ff.

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Table 1
W2RS 144 MHz EME
Stations Worked and Their Antennas Employed (1)

Station	Array (2)	Estimated Gain (dBi)	Notes
W5UN	48x 4.8 WL	33.3	Worked with 50W CW
W5UN	48x 4.7 WL	32.5	Worked with 150W SSB
W5UN	32x 4.7 WL	30.4	Random QSO, Worked with 130W CW
KB8RQ	24x 5.7 WL	30.0	Random QSO, mutual ground gain
SM5FRH	24x 5.2 WL	29.7	
KB8RQ	24x 4.8 WL	29.5	Random QSO
KB8RQ	32x 3.2 WL	29.3	Worked with 130W CW
N5BLZ	16x 5.2 WL	28.0	
KB8RQ	16x 4.8 WL	27.8	
W4ZD	16x 4.8 WL	27.8	Mutual ground gain
WB5LBT	16x 4.8 WL	27.8	
K1WHS	24x 2.2 WL	27.0	Mutual ground gain
N5BLZ	12x 4.7 WL	26.7	
SM7BAE	16x 3.1 WL	26.3	Worked with 130W CW
K2GAL	8x 5.9 WL	26.1	Mutual ground gain
DL8DAT	16x 2.8 WL	26.0	
VE7BQH	336el Coll	25.7	

AF9Y	6x 6.2 WL	25.4	
HB9CRQ	8x 4.8 WL	25.0	
K9MRI	8x 4.8 WL	25.0	
LA8YB	8x 4.8 WL	25.0	
I2FAK	8x 4.7 WL	25.0	
VE7BQH	224el Coll	24.2	Worked with 130W CW
G8MBI	224el Coll	24.2	
OK1MS	8x 3.6 WL	24.1	
SM2CEW	6x 4.2 WL	23.6	Mutual ground gain
K2GAL	4x 6.2 WL	23.3	Mutual ground gain
K3HZO	6x 3.2 WL	23.1	Mutual ground gain
N1BUG	24x 4el Quad	22.8	Mutual ground gain
AA4FQ	4x 5.1 WL	22.3	Ionospheric scintillation
W7VXW	4x 4.8 WL	22.2	Strong libration peaks
KI3W	4x 4.2 WL	21.9	Mutual ground gain
WB2JHG	8x 1.5 WL	21.6	Mutual ground gain
WB2OYC	4x 2.2 WL	19.7	Mutual ground gain

Average conditions prevailing:

Sky noise	289	K
Path loss over perigee	0.8	dB
System degradation (3)	2.5	dB

Notes:

(1) Except as noted, W2RS output power was 150W CW to one 3.2 WL Yagi.

(2) Except as noted, all antennas are multi-Yagi arrays where n WL is the boom length of each Yagi in wavelengths.

(3) System degradation, as defined by W5LUU, is the overall S/N degradation with respect to ideal conditions (perigee and sky noise of 165 K) assuming a receiving system noise temperature of 80 K.

Physical Principles of 50 MHz F_2 Propagation

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Introduction

Whether it arises from a desire to work the rare ones, a need to plan a vacation, or scientific curiosity, all of us who have spent countless hours listening (usually to noise) on six meters have all wished we could predict precisely when the band would be open. Unfortunately, there are no simple approaches to this issue. Nevertheless, some pieces to the F_2 puzzle are known and this paper will discuss a number of them.

It should be noted at the outset that six-meter F_2 propagation is a very improbable event, from a *statistical* point of view. While this may seem obvious, it has a very important consequence. "Unlikely" events in complex physical systems are often the result of a *combination* of factors, some of which, themselves, may be fairly unlikely. This is certainly the case with most six-meter F_2, where propagation is almost always at or very near the ultimate edge of what is possible.

Predicting band openings does not involve predicting a single event, but rather a coincidence of several events, and not always the same ones or in the same combinations. We do not even know for sure what all of the factors are, much less how they interact. On the other hand, there are a number of effects that are known to be significant and most of them involve the Sun.

The Ionosphere and the Sun

The Earth's atmosphere extends from the surface to heights well in excess of a 1,000 km. The density of the static atmosphere is highest near the surface and decreases progressively as one goes upwards. Most of the atmospheric mass is located very near the Earth's surface, with more than half of the mass contained within just the first 5 km.

The Sun, on the other hand, pours its radiation down into the atmosphere from the topside. Thus, the upper regions of the atmosphere receive the full brunt of the Sun's ultraviolet, x-rays, cosmic rays, and so forth. The radiation interacts with the atmosphere on its way downward, and as it does, portions of the radiation are absorbed at different levels.

The interactions between solar rays and the air molecules and atoms are very complicated. There is a whole complex of interesting chemistry that can take place at these rarefied heights that normally has no importance at lower levels. What wavelengths are absorbed at what levels is determined in part by the chemical components and particle densities found at each level. Generally, ultraviolet radiation is absorbed fairly high in the atmosphere, while x-rays penetrate somewhat lower, and cosmic rays go lower still.

When solar photons do get absorbed it is generally as a result of a collision with an atom or molecule. Often such collisions occur with sufficient force to knock off one or more electrons from the atom or molecule struck. This leaves behind a missing (absorbed) photon and positively and negatively charged ions. Usually the positive ions are the comparatively heavy cores of the atoms or molecules and the negative ions are the relatively light electrons. It is the electrons that play the dominant role in radio propagation.

* The National Optical Astronomy Observatories is operated by the Association of Universities for Research in Astronomy under a cooperative agreement with the National Science Foundation.

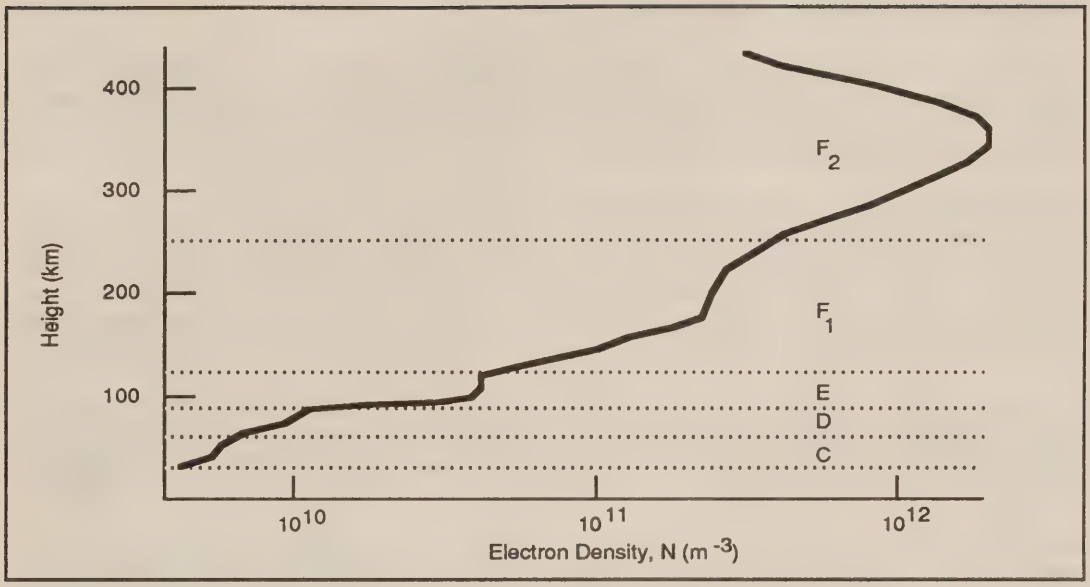

Figure 1. A typical plot of the electron density as a function of height showing the C, D, E, F_1, and F_2 layers.

The net effect is that the passage of solar radiation leaves behind several distinct layers that are characterized by enhanced levels on ionization. The F_2 layer is the highest of these, both in terms of distance above ground and in terms of electron density. This layer extends from roughly 250 km above the Earth to over 500 km, with a peak electron density in excess of 10^{12} e/m^3 around 350 km. The solar extreme-ultraviolet radiation (EUV) is the principal source of ionization in the F region. The table below shows typical characteristics of the various layers. It should be noted that the "boundaries" between the layers are ill-defined and for sake of brevity the list of ionizing radiation is not entirely complete.

Ionospheric Layers

Layer	Height (km)	Density (e/m^3)	Ionizing Radiation
C	30 - 60	5×10^9	Cosmic Rays
D	60 - 90	1×10^{10}	Hard X-Rays
E	90 - 120	8×10^{10}	Soft X-Rays
F1	120 - 250	5×10^{11}	Extreme Ultraviolet
F2	250 - 500	3×10^{12}	Extreme Ultraviolet

Ionospheric Radio-Wave Propagation

When an upward moving radio wave reaches a given layer of the ionosphere, the electric field in the wave forces that layer's electrons into a sympathetic oscillation at the radio frequency of the passing wave. A certain amount of the wave energy is given up to this mechanical vibration of the electron cloud. As a result, the passing wave gets weaker.

At this point there are two general types of things that can happen. In one extreme, the electron cloud may be in a dense enough part of the atmosphere that the oscillating electrons collide with other particles almost immediately (say, in less than one RF cycle). When that happens, the wave energy that was first given to the mechanical electron oscillation is now given up as heat to the atmosphere before anything else can happen. This energy is lost forever as far as the wave is concerned. This is another way of saying that the radio wave undergoes a loss due to *absorption*.

This is precisely what happens to signals below about 10 MHz when they encounter the daytime D layer. The average frequency of collisions between particles in this region during the day is about 10 million collisions per second. So, it strongly absorbs radio frequencies below 10 MHz. The lower the frequency, the more the absorption.

At the other extreme, if the collision frequency in the layer is significantly *less* than the wave frequency, *and* if the electron density in the vibrating cloud is *greater* than a certain critical value, then the whole cloud can act more like a static reflector. Almost all of the wave energy is given up to the vibration in a very short distance, all the electrons vibrate in phase, and together they reradiate the original wave energy back downward again. Thus, the wave "skips" off the ionospheric layer, hopefully to some distant point.

It should be noted that in most cases what actually occurs is something intermediate to these two extremes. Some amount of absorption always occurs. Moreover, when the electron density does exceed the critical skip value, it does so gradually. Rather than a discontinuous reflection, there is a *refraction* of the wave, a more gradual bending back around toward the ground. Even when the critical density is not reached (and the wave passes through the ionosphere and escapes into space), a certain small fraction of the wave is reradiated by the vibrating cloud and some of this new signal goes downward as a form of ionospheric scattering.

If skip is to occur, the Maximum Usable Frequency (MUF) at which a wave propagates is determined by the maximum electron density that the wave encounters in the ionosphere *and* the angle at which the wave hits the reflecting/refracting layer. Suppose one fixes the angle by considering a radio signal sent *straight up*. From electromagnetic theory one can calculate f_o, the highest frequency that the ionosphere can reflect that signal straight back down (the "vertical MUF").

$$f_o = \sqrt{\frac{Ne^2}{\varepsilon_0 m}}$$

Here, N is the number density of electrons, e is the electron charge, ε_0 is the permitivity of free space, and m is the mass of the electron. The "angle of incidence" in this example is zero (that is, the angle to the vertical; obviously the angle to the F layer is the compliment of this, 90°).

Now suppose we consider a signal that is sent off very near the horizon (that is, with a low angle of radiation). Due to the curvature of the Earth and the ionosphere, this wave will hit the ionosphere at an angle of incidence that is on the order of 70° to 80°. The exact value depends on the height of the ionospheric layer and angle of radiation. The MUF can be calculated from the following expression:

$$f_{max} = f_o \sec \phi$$

where ϕ is the angle of incidence. Here one sees the dependence on both the electron density (hidden in f_o) and the angle, ϕ. The secant term is often referred to as the "M factor".

$$f_{max} = M f_o$$

For the F_2 layer, M ≈ 3.4, and for the E layer, M ≈ 5.4. The importance of bringing up the angular term will become apparent shortly.

Notwithstanding the fact that the F_2 layer retains some of its ionization even at night, all of the foregoing should make it clear that *six-meter F_2 propagation is normally a daytime affair*. (For those who live in the tropics there is an important exception, but more on that later.)

Seasonal F-Layer Effects

The amount of ionization in a given layer at a given time depends on the dynamic balance between those processes causing ions to be produced and those that causing ions to be lost (by returning to their original neutral state). Put another way, the ion density depends on the amount of radiation arriving from the Sun causing the *production* of ions, minus the *loss* of ions due to electrons being recaptured by positive ions. The rates and mechanisms of these processes vary widely from layer to layer.

For example, the underlying (neutral) density of the D layer is much higher than that of the F layer. Consequently, in a given length of time, electrons and positive ions there are much more likely to collide and recombine. As a result, by comparison to the F layer, the maximum D-layer ionization is held down during the day by collisional losses, and the D layer disappears in minutes when the Sun goes down. By contrast, ions last a lot longer in the F layer. Even late at night, there are often enough ions left to support HF communications.

There is another effect that is important in understanding the production of ions and that is the *angle* with which the sunlight impinges on the top of the Earth's atmosphere. When the rays arrive at an angle to the vertical the energy is spread out over a larger area, and thus the energy density at any one spot is reduced. Therefore, more electrons are being produced overhead at local noon than overhead near sunrise or sunset. Not only is there a diurnal effect, but there is a seasonal one as well. In local winter the hemisphere in question is tipped partly away from the Sun and the various layers receive proportionately less radiation. Consequently, in the northern hemisphere fewer daytime F-layer electrons are produced at a given time of day in January than in July.

However, remember that production is only half the equation. There is a peculiarity in the F_2 layer, not found in the other layers, called the *winter anomaly*. Although daytime ion production is higher in the summer, there are seasonal changes in the molecular-to-atomic ratio of the underlying (neutral) atmosphere that cause the summer ion loss rate to be *even higher*. The result is that the increase in the summertime loss overwhelms the increase in summertime production, and *total* F_2 ionization is actually *lower*, not higher, in the local summer months. Put the other way around, daytime F_2 electron densities, and thus MUF's, are higher in the local winter.

Measured at the "half-width", the winter peak starts in October and lasts until May or June. Most years there is a fairly flat peak between December and April. It is interesting to note that during the peak years of solar cycles 18 through 21, October was almost always the beginning half maximum, whereas the ending half maximum varied from April to July. The ending months were pretty consistent within a given cycle, but cycles with higher maxima favored May with an occasional April, while those with lower maxima favored June with an occasional July.

Interestingly, winter anomaly shows the most seasonal fluctuation near solar maximum. Here the local winter daytime MUF's are twice as high as the daytime summer values, while they are only about 20% higher during solar minimum. The central message in all of this is that, on average, F_2 propagation *between points on the same side of the equator* will be much better in the local winter and near solar maximum.

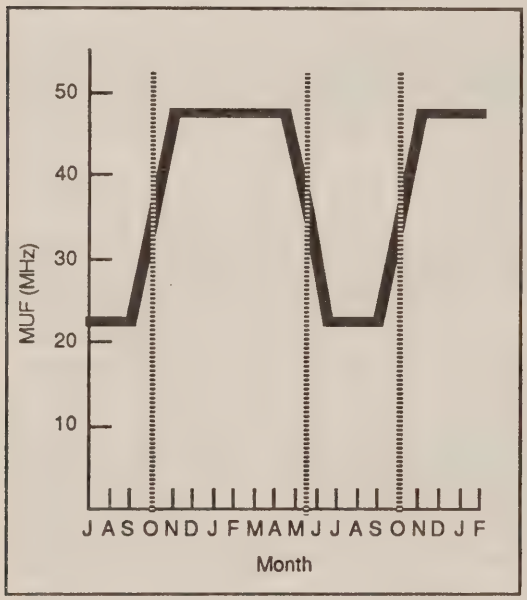

Figure 2. A schematic plot of the Northern Hemisphere variations of MUF due to the winter anomaly. The MUF values shown are typical for mid day at mid latitudes near solar maximum. The October onset has been very stable for the preceding four solar cycles. While the May-June decline has varied from April to July.

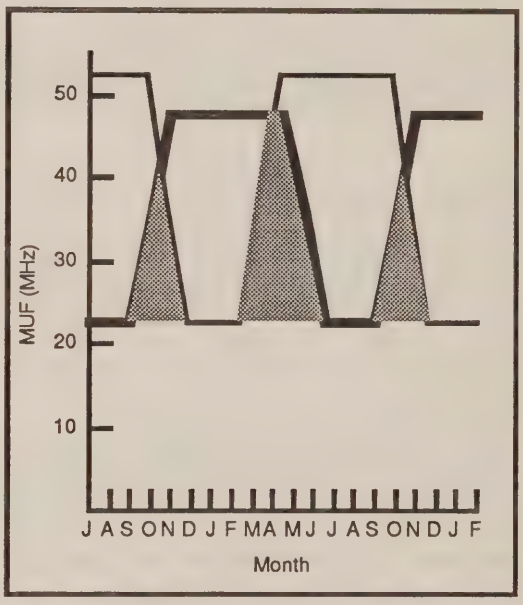

Figure 3. A schematic showing the overlap of the northern and southern winter anomalies in the western hemisphere, as modified by the effect of the magnetic equatorial anomaly. The shaded areas show the most likely times of year for north-south transequatorial multihop.

If one is interested in a double hop (or more) along generally north-south paths, then the winter anomaly comes into play in another way. If it is wintertime in one hemisphere, it will be summertime in the other. So, for example, in January the first hop of a two-hop path from North to South America might make it, only to have the second hop fail due to the absence of the winter effect at the second skip point. Obviously, the best times of year for such a path would seem to be in the Fall and Spring when the winter anomaly effects overlap a bit in both hemispheres.

The winter anomaly is not the only seasonal effect. Many two-hop (or more) north-south openings on six meters seem to have no evidence of stations at the end of the *first* hop. This is often probably due to the ionospheric equatorial bulge known as the *equatorial anomaly*. Within ±20° of the Earth's

magnetic equator there is a pronounced outward bulge in the ionosphere. Though generally regarded as an afternoon or early evening phenomenon, it occurs at other times as well. It is thought to be produced by a combination of a persistent thickening of the F layer near the equator and a diurnal fountain effect. The "afternoon fountain" seems to be the result of the build up of west-to-east electric fields in the equatorial E layer that, in combination with the Earth's magnetic field and ionospheric winds, pump electrons upward from the E layer and lower reaches of the F layer into the upper F_2 layer.

It was pointed out earlier that the angle with which the radio wave encounters the layer is also a factor in determining the MUF. The equatorial bulge produces two regions, one north of the equator and the other south, where the ionosphere is systematically tilted. Of particular interest are the points at the "corners" where the generally spherical ionosphere is bent upwards to form the bulge.

This upward tilt is such that an upcoming wave hitting the near point will do so at a shallower angle to the tilted layer (at a larger angle of incidence) than it would to the usual spherical layer. This means that it will have a higher MUF for the same value of electron density. That is, the M factor is larger than 5.4, perhaps by quite a bit. The wave is not bent all the way back toward the ground. However, it is bent enough to cross the equator and hit the tilted layer on the far side, *without ever coming back to Earth.*

This so called "chordal hop" to the second tilted region produces another small-angle reflection that *is* just enough to return the signal to the Earth on the far side of the equator. The effect is a kind of double hop with nothing in between, and at a higher MUF than could otherwise be supported. Since the "bulge" effect does produce higher MUF's, this is often the likely cause of multi-hop north-south propagation of six meters. Moreover, it is a fairly low-loss path. The wave never comes down at the path midpoint, so it avoids two passes of D-layer absorption that normal double hop would have encountered.

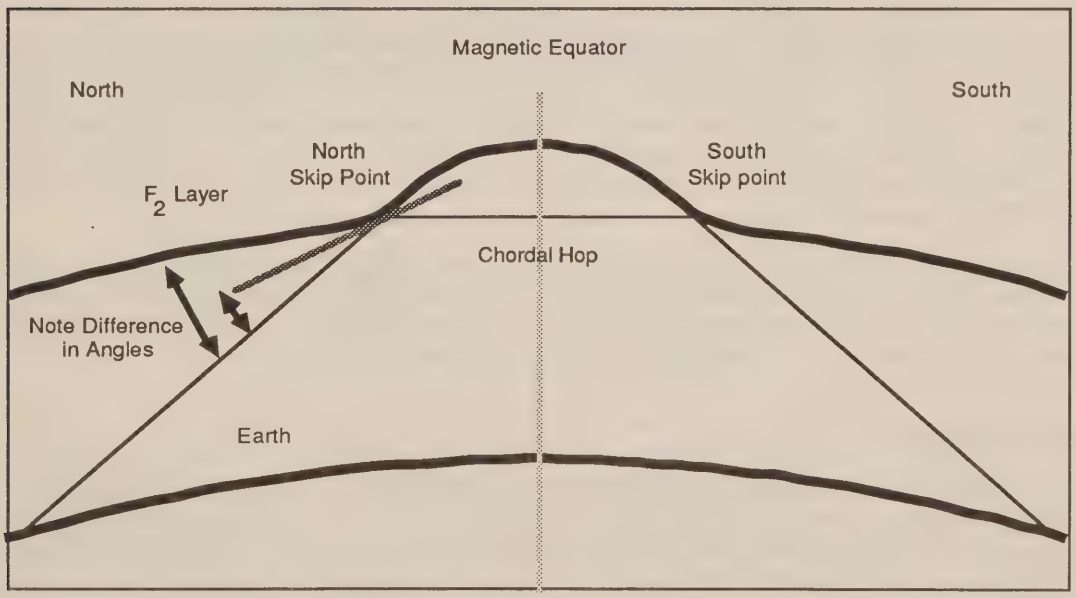

Figure 4. A diagram of a transequatorial chordal hop off the tilted north and south skip points. These points lie about 20° north and south of the Earth's magnetic equator and can be major contributors to daytime transequatorial six-meter propagation from mid latitudes and clearly cause nighttime TEP in the tropics.

In order for this form of propagation to function, *both* the north-side and south-side tilted regions need to be ionized enough to make the path work. Again, if either one is insufficient then the whole path fails. At lower frequencies there is often a fair amount of margin, but at six meters this usually means that the best chance occurs when both sides of the equatorial bulge are equally illuminated by solar radiation, and this situation only occurs around the autumn and spring equinoxes when the Sun is most nearly over the equator.

Normally one would think that this would occur in late September and late March. However, the Earth's magnetic field is tilted with respect to the geographical coordinates. In the western hemisphere the magnetic equator can be nearly 11° south of the geographic equator. This means that the "magnetic equinoxes" occur about a month or more earlier (August and February) for paths between North and South America. From the point of view of a station in North America, as the path of interest swings around further east or west, the magnetic equinoxes are more nearly the same as the geographical ones. Consequently, the date of the magnetic equinox is dependent on the amount of east or west component included in the north-south path, and where you happen to be on the Earth.

There is also an interaction between the balanced illumination at the magnetic equinoxes and the double-hop winter anomaly effect (which is geographical, not magnetic). For example, consider a path between North and South America. Here it should be noted that in part as a consequence of the location of the magnetic equator, MUF's are frequently higher over South America than North America. During the Fall equinox period, on the northern side of a path August is too early for much help from the (northern) winter anomaly. By contrast, the southern skip point is bolstered by both the winter and equinox effects and has a substantially higher MUF than the northern point. If this path is going to succeed it will likely have to wait until October when the northern skip point is in better shape. Put another way, by October the northern and southern skip point MUF's will be about the same, as they pass each other going in opposite directions.

During the Spring period, February, as well as March and April, are all still in the peak for the north end. Even though the southern point is in the summertime it has a higher MUF to begin with, and the equinox effect adds even more. The result is that the southern point MUF may well be higher than the northern point MUF, despite the *absence* of help from the winter anomaly. In the meantime the northern point is as good as it will ever get, *because* of the winter anomaly. Consequently, for generally *north-south paths across the magnetic equator*, periods more nearly centered on October and March are generally the best, and often the Spring gives more consistent daytime transequatorial performance.

Of course, unless one has an E-layer link up, or some other funny business, another requirement is that the stations each be close enough to the nearest ±20° tilted skip point to illuminate that point by radio line of sight. Based purely on geometry, the southern half of the U.S. has an advantage for South American paths and the southwestern states for the South Pacific.

The Solar Cycles

For reasons that are still unknown, the general background magnetic field of the Sun reverses polarity every 11 years or so. Thus, the Sun experiences a 22-year magnetic polarity cycle of north to south to north again. This effect is accompanied by a cycle of solar activity that reaches a peak approximately every eleven years. The peak itself can be fairly broad, having significant effects for three or four years.

The solar activity cycle is seen in virtually every kind of signal we can receive from the Sun, from radio waves to x-rays. Not surprisingly then, the amount of ionizing radiation impinging on the atmosphere varies with this same pattern, including the EUV that is the principal source of the F_2 layer.

Consequently, propagation is decidedly better near solar maximum, but the seasonal effects are still superposed on the general enhancement seen during the maximum.

There is a second kind of "solar cycle" produced by the fact that the Sun rotates on its axis every 27 days or so, and the fact that "activity" on the surface of the Sun is generally confined to a few specific regions at any one given point in time. As a result, if the Sun is active at all, it is quite common for one side to be active and the other side relatively quiet. As the Sun rotates there is often a very pronounced 27-day cycle in the radiation reaching the Earth. This 27-day cycle definitely has an effect on propagation, though many believe it is not as pronounced as it might seem it should be.

It should be noted that the active solar longitudes change over time. The 27-day cycle of activity commonly repeats for several cycles and then is interrupted as old solar active regions fade and others emerge. When new active regions do develop, typically at some other longitude, the cycle will be reestablished, but with a different phase. In other words, knowing that a particular two-week period was active last month is a pretty good predictor that the same two-week period this month also will be active. However, it is a very poor predictor of activity during that period six months from now.

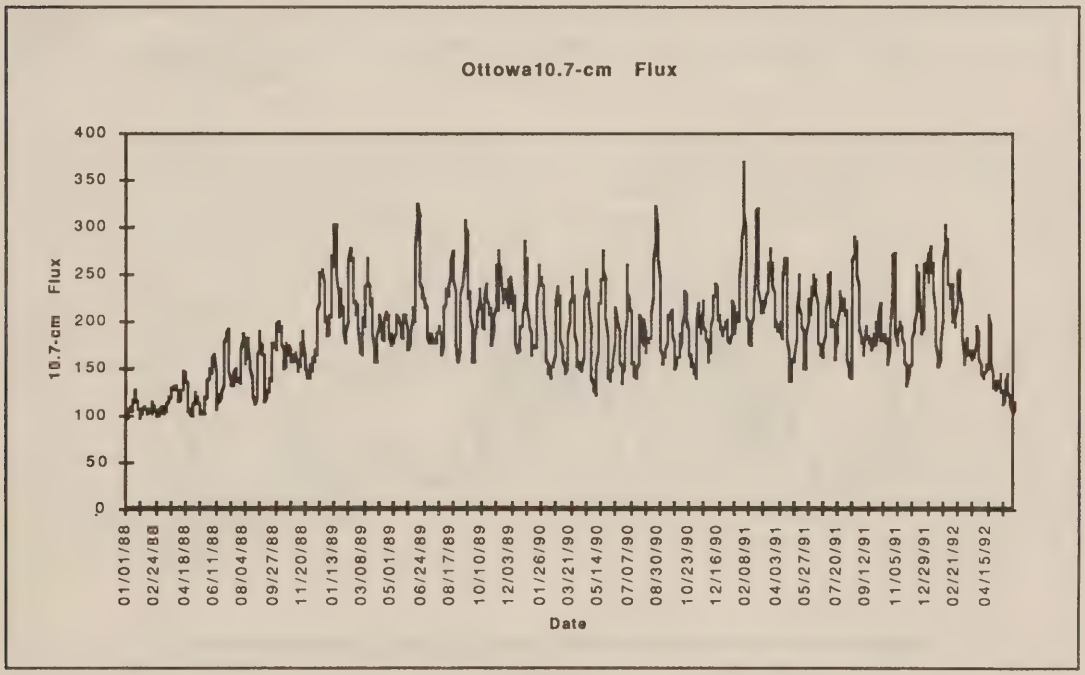

Figure 5. This plot of the 10 cm flux extends from January 1, 1988 to June 5, 1992 and encompasses most of the peak of the current solar cycle (Cycle 22). It shows the rise and fall of the average 10 cm background over the peak. In addition, it clearly shows the 27-day rotation cycle. Note the interruptions and restarts that occur every several cycles.

There is no doubt that during solar maximum, and especially during periods of high activity, the amount of EUV reaching the ionosphere increases substantially. In principle, this should mean better propagation. People have tried for some time to get direct measurements of the EUV radiation with an eye toward making short-range predictions of propagation conditions, but so far these have not been very successful.

Very little of the F_2-producing EUV reaches the Earth's surface, precisely because it is absorbed making ions in the F layer. A number of spacecraft have carried EUV sensing instruments, but generally these detectors are susceptible to damage from the very radiations they wish to measure. As a result, their sensitivity changes in time, making accurate absolute measurements very difficult to get.

For many years scientists have been using the 10.7-cm solar radio flux as a "proxy" for EUV emission. This radiation is formed at about the same level in the Sun as the EUV, and has a similar temperature sensitivity. Under relatively quiet solar conditions the 10-cm and EUV fluxes track pretty well. However, there is a component of the 10 cm emission that is also sensitive to other forms of activity including those that produce x-rays. Consequently, during periods of *high activity* 10 cm is *not* a good indicator of the strength of the EUV radiation reaching the F layer. In fact, it tends to overestimate the EUV considerably. While there is a good correlation between the long-term average of the 10-cm flux and F_2 propagation (as there is with sunspots, flare counts, and many other activity measures), *there is very little day-to-day correlation.*

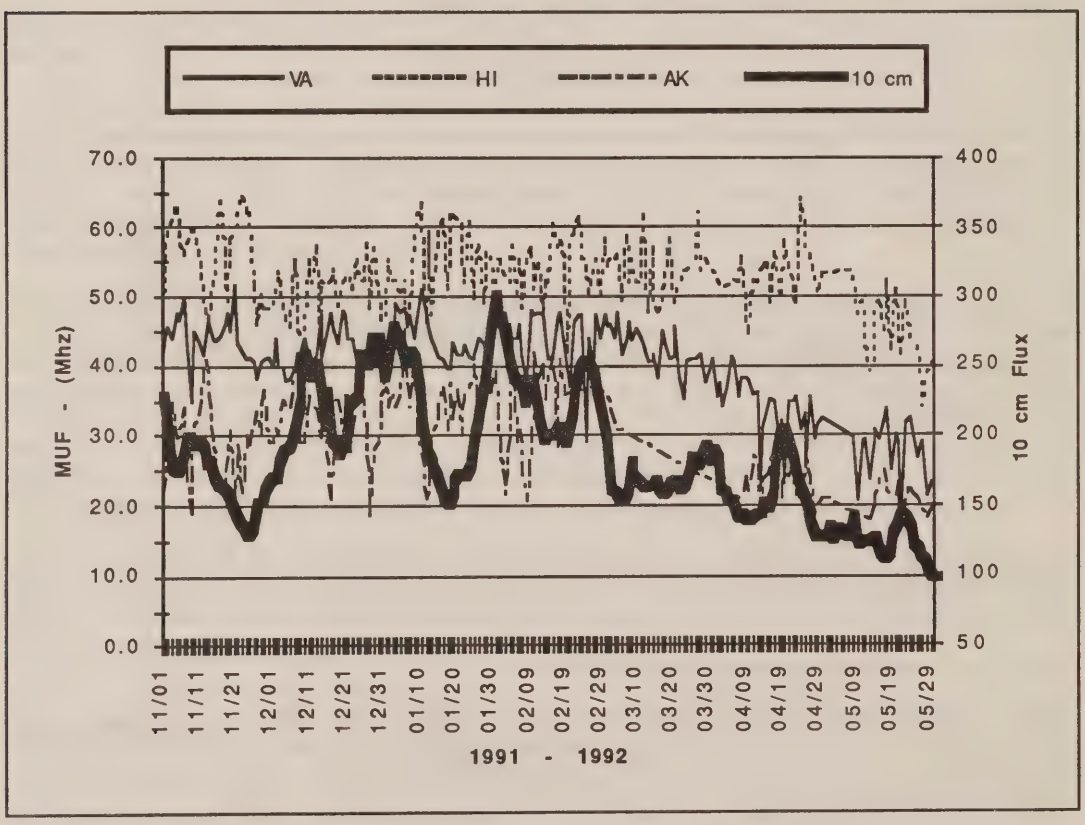

Figure 6. This plot shows the maximum daily overhead skip point MUF for sites in Virginia, Hawaii, and Alaska, and the 10 cm flux from November 1, 1991 to May 31, 1992. Notice the effects of latitude due to solar angle. In particular, notice that while the MUF's track the general long-term average value of the 10-cm flux there is little relationship between the daily fluctuations. The combined effect of lower solar activity and the winter anomaly on the MUF is seen in the March through May period.

This is not to discount keeping track of the 10 cm flux; it is a useful indicator of the general level of solar activity. Unfortunately, during solar maximum one never knows whether "high flux numbers" mean high EUV and high F-layer MUF's, or high x-rays and high D-layer absorption. It is certainly true that long periods of time with high flux numbers will contain periods of good propagation, but it is very hard to say whether the openings will come on individual days when the flux is 300 or on days when its 150.

Other Solar Effects

Perhaps the most talked about solar events are flares. These more or less random high-energy outbursts produce a variety of effects, and no two flares are ever exactly alike. Flares generally occur in active regions and, if they are to affect the Earth, the active side of the Sun must face the Earth. To this extent they are weakly predictable. There is also a mysterious 157-day period associated with flares, and most other solar activity measures, that so far has been ignored by most propagation prognosticators.

The impact of solar flares is very unpredictable. Generally there is a large outburst of x-rays associated with big flares. This usually produces an almost immediate increase in both the amount and maximum frequency of D-layer absorption. This often results in widespread "blackouts" of the HF spectrum on the daylight side of the Earth that may last for many hours.

There may also be outbursts of EUV in some flares that produce a very rapid response in the F layer. However, while the x-ray flux may change by a factor of 100 or even a 1,000 in a major flare, the EUV may only go up by a factor of two to five. Sometimes excellent six meter openings do result from a flare, provided that the D layer does not get in the way (which it generally does not). At other times flares seem to hurt rather than help.

Of course, another possible effect of flares are geomagnetic disturbances. All flares blow some material away from the surface of the Sun. If the trajectory of this material takes it to the Earth (it often misses), then it will arrive with a few hours to a couple of days and may produce profound disturbances in the geomagnetic field. This can be either good or bad for F_2 propagation.

Storms effecting the F layer often have a positive and then negative effect on the electron densities, and hence the MUF, on the time scale of several hours. At mid latitudes, electron densities can climb as much as 20% above the ambient and then drop to 30% below the ambient all over a period of 24 hours or less. On the other hand, in equatorial regions a general enhancement of 5 - 10% is often seen, with no pronounced negative phase.

Nighttime TransEquatorial Propagation (TEP)

One of amateur radio's many propagation discoveries was that stations located close to the magnetic equator are often able to communicate at 50 MHz by way of the F layer in the dead of night, over long paths that cross the magnetic equator. The basic mechanism is thought to be the equatorial anomaly discussed earlier. That is, the afternoon fountain effect causes enhanced electron densities and tilted layers to form within 20° of the magnetic equator late in the day or early in the evening. These conditions can persist long into the night with some contacts taking place long after local midnight.

For stations who have the good fortune to be in the TEP zone, the paths themselves do not have to be especially north-south. As long as the two stations are on opposite sides of the magnetic equator they can be at a considerable angle to the north-south line. All that is necessary is that the two ±20° corners be at the chordal skip points.

It is fair to say that this propagation mode is not well understood. Moreover, there are many reports of stable nighttime contacts between tropical stations that behave like TEP, but where the stations are on the same side of the equator. The explanation for this phenomenon is a matter of conjecture but it likely involves odd reflections from the ±20° points.

Some Conjecture

The two basic ingredients for a propagation path are ionization and angle, in the right combinations. If we restrict our thinking to the HF spectrum it is easy to explain the bulk of the propagation in terms of ionization alone. This is simply because there are generally enough ions to make some path work at almost *any* angle. As stated earlier however, at six meters, F_2 usually relies on combinations, and combinations of combinations.

While the bulk of the previous discussion has been been focussed on F_2, there are a number of ways that a signal can get to, or from, the F layer. For example, if the F-layer ionization was not quite enough to support the angle for an F_2 hop directly from the ground, the partial bending of the wave on the way up by an E-layer cloud (itself not sufficient to cause a reflection) might cause the wave to hit the F layer at a shallower angle and thus produce a high enough M factor to make the F hop work after all. Similarly, a tilted E layer could produce the same effect.

On the other hand, a real reflection from an E layer cloud might skip a signal, originating from a station far from the magnetic equator, close enough to the equator to take advantage of the equatorial anomaly. Another possibility is the lengthening of a two (or more) hop F_2 path by a reflection from the *topside* of an E cloud in between the two F hops. This avoids the two intermediate passes of D-layer absorption, as well as any scattering of the signal by the ground at the path midpoint.

A very poorly understood area is the role of F-layer distortions. Except for the equatorial anomaly, much of the preceding discussion has implicitly assumed that the ionosphere is a smooth spherical surface. This is an idealized picture that is really not true at all. The F layer is a convoluted surface affected by the motion of the subsolar point, ionospheric wind patterns, and even tropospheric weather.

There are a variety of traveling wave-like structures that are known to exist that can produce moving "ripples" in the ionospheric surface. Similarly, there is evidence to suggest that that from time to time there are localized bulges or "domes" not associated with the equatorial anomaly. Any effect such as these that produces tilting of the F layer has the potential to locally raise the MUF because of the angle of incidence M-factor effect. The sources of these distortions are not clear. When the other contributing factors to the 50-MHz MUF are not quite enough to open the band, these subtle effects, no doubt, can play an important role. But since they relate to a kind of "ionospheric weather" situation, they are very hard to predict with our present knowledge.

Even random irregularities in the E or F layer can have an effect. These can produce scattering that again can inject (usually weak) signals into the F layer at angles more suitable for subsequent skipping. Those who listen for 48 and 49 MHz television carriers as band condition indicators often hear signals that arise from the combination of high power and scattering injection.

Summary

When F_2 propagation occurs on six meters it is usually the result of the coincidence of a number of different phenomena that, together, produce suitable combinations of ionization levels and radio-wave angles of incidence. Solar extreme-ultraviolet radiation is the principal source of ionization.

Consequently, the Sun is the source of many of these effects. However, the full range of operational factors and their modes of interaction is not known. The diurnal cycle, the solar activity cycle, solar rotation, solar flares, and a variety of terrestrial effects are all known to contribute. Evidence suggests that there are a number of other poorly understood factors. Various phenomena that affect the angle of incidence may make more significant contributions to the basic occurrence of F_2 at 50 MHz than at lower frequencies.

So, when is the band open? Well it is somewhat like playing a slot machine with lots of wheels. There are certain combinations that come up winners to some degree or another. There is an important difference from a slot machine though. The odds of some of the wheels coming up favorable is not entirely random. Within limits, the daily wheel, the solar cycle wheel, and the 27-day wheel are all predictable to some degree. And just to make the game interesting, there are several more wheels we do not know about. And more tantalizing still, in time we may be able to figure them out. We can say that, for stations at magnetic mid latitudes, the favored times are as follows:

Same Hemisphere (North or South)

Daytime, local winter (November to May in the north), Near solar maximum, During the peak two weeks of the current 27-day cycle, *plus unknown factors.*

Transequatorial Paths

Daytime, October-November and March-April, Near solar maximum, During the peak two weeks of the current 27-day cycle, *plus unknown factors.*

Not withstanding these patterns, it is obvious that this is truly an unfinished story. Even though the list above addresses the most probable times, it is clear that F_2 can pop up at any time. Many openings have happened when none of these conditions were present. This only goes to underscore the importance of the "unknowns" and to present a challenge to the community to keep listening and to keep track of what they hear and work.

Acknowledgements

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BIBLIOGRAPHY OF 33-CM (902- to 928-MHz) ARTICLES

By Ron Neyens - NØCIH - May, 1992

At 0001Z hours on September 28th, 1985, the FCC released the 33-cm band (902- to 928-MHz) for Amateur Radio use. Since that time, numerous articles have been published to encourage, foster, and support new and continued activity on this band. The following is a compilation of 33-cm articles including the author and publication source.

AMPLIFIERS

"A High-Power Cavity Amplifier for the New 900-MHz Band," by Bob Sutherland - W6PO and William Orr - W6SAI; QST, November 1982

"A 14 Watt, 900-950 MHz Low Cost Amplifier Design," by David Miller; RF Design, April 1985

"Monolithic RF Amplifiers," by Jerry Hinshaw - N6JH; Ham Radio, March 1986

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"CGY-40 GaAs MMIC Amplifier," by Al Ward - WB5LUA; Proceedings of the 1986 Microwave Update, August 1986

"Two 7289's On 903-MHz," by Ken Schofield - W1RIL; Proceedings of the 1987 Mid-Atlantic States VHF Conference, October, 1987

"Microwave Building Blocks: 800-950-MHz Linear Amp," by Dave Mascuro - WA3JUF; Proceedings of the 1987 Mid-Atlantic States VHF Conference, October, 1987

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25th Central States VHF Society Conference

Antenna Gain Measurement Results

July 26, 1991 - Cedar Rapids, Iowa

= Indicates Reference Antenna * = Indicates Category Winner COM = Commercial HB = Homebrew

144 MHz

	GAIN (dBd)	CALL	COM/HB	DESCRIPTION
*	14.9	AF9Y	HB	22 ELE. YAGI, YO/MN/NEC OPTIMIZED
	14.1	W1JR	COM	17 ELE. YAGI, CUSHCRAFT/W1JR DESIGN
	12.9	W1JR	COM	13 ELE. YAGI, CUSHCRAFT/W1JR DESIGN
	12.2	NØCIH	HB	14 ELE. YAGI, MODIFIED CUSHCRAFT 214B
#	10.0	WBØTEM	HB	8 ELE. YAGI, REFERENCE ANTENNA
	9.7	AJØE	HB	5 ELE. YAGI, KØIWA DESIGN
	0.2	WQØP	COM	1 ELE. HALO, CUSHCRAFT

220 MHz

	GAIN (dBd)	CALL	COM/HB	DESCRIPTION
*	14.5	WBØGGM	HB	16 ELE. YAGI, MODIFIED WBØTEM DESIGN
	13.7	KCØP	HB	15 ELE. QUAGI, 222-MHZ N6NB/KCØP DESIGN
#	13.0	WBØTEM	HB	13 ELE. YAGI, REFERENCE ANTENNA
	-2.0	WA5VJB	COM	HARPOON MISSILE TELEMETRY ANTENNA

432 MHz

	GAIN (dBd)	CALL	COM/HB	DESCRIPTION
*	18.2	WA2PHW	HB	38 ELE. YAGI, YO OPTIMIZED
	18.0	WA2PHW	HB	31 ELE. YAGI, YO OPTIMIZED
	17.8	KB4WM	COM	33 ELE. YAGI, HB2A
	17.1	WBØGGM	HB	24 ELE. YAGI, 17 FT. BOOM
	16.4	WBØGGM	HB	24 ELE. YAGI, 17 FT. BOOM
	15.8	NØCIH	HB	19 ELE. YAGI, MODIFIED K2RIW
#	15.2	WBØTEM	HB	19 ELE. YAGI, K2RIW REFERENCE ANTENNA
	12.1	KCØP	HB	8 ELE. QUAGI, N6NB DESIGN
	9.3	WØPPF	HB	11 ELE. YAGI
	3.2	KØCQ	HB	LOGARITHMIC DISH FEED
	-0.2	WA5VJB	COM	HARPOON MISSILE TELEMETRY ANTENNA

902 MHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
#	14.3	WA5VJB	HB	YAGI, REFERENCE ANTENNA
	12.3	W5UGO	COM	FEEDHORN, FAA TEST
	10.7	WA9ENA	COM	6 ELE. YAGI, ANTENNA #2
	10.6	WA9ENA	COM	CORNER REFLECTOR, DB PRODUCTS
	10.2	WA9ENA	COM	6 ELE. YAGI, ANTENNA #1
*	7.5	KØCQ	HB	LOGARITHMIC DISH FEED

1296 MHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	21.1	WB9SNR	HB	48-INCH PARABOLIC DISH, FEED #1
	21.0	WB9SNR	HB	48-INCH PARABOLIC DISH, FEED #2
	20.2	WA7CJO	COM	44 ELE. YAGI, KLM 1.2-44LBX
	19.9	KBØHH	HB	48-INCH PARABOLIC DISH, COFFEE CAN FEED
	19.9	AA9D	COM	55 ELE. LOOP YAGI, DOWNEAST MICROWAVE
	14.4	W5UGO	COM	FEEDHORN, FAA TEST
#	14.2	WBØTEM	HB	11 ELE. YAGI, REFERENCE ANTENNA
	12.7	WA5VJB	HB	ROEDERER CROSS, AMSAT PROTOTYPE
	11.2	WDØBWQ	HB	QUAGI ANTENNA
	9.8	KA5WOT	COM	FEEDHORN
	9.4	KA5WOT	HB	DUAL LOOP YAGI
	8.8	K5PJR	HB	4-TURN HELIX
	8.7	WDØBWQ	HB	9-TURN HELIX
	8.0	K5PJR	HB	BANANA PEEL ANTENNA
	6.0	KØCQ	HB	LOGARITHMIC DISH FEED
	5.7	WD4MUO	HB	DISH FEED

2304 MHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	27.9	WB9SNR	HB	48-INCH PARABOLIC DISH, COFFEE CAN FEED
	26.6	WB9SNR	HB	48-INCH PARABOLIC DISH, DIPOLE FEED
	26.1	KBØHH	HB	48-INCH PARABOLIC DISH, COFFEE CAN FEED
	21.4	NØCIH	HB	36-INCH PARABOLIC DISH, WA3MUX 3-BAND FEED
	13.5	W5UGO	COM	FEEDHORN, FAA TEST
#	13.4	WA5VJB	HB	FEEDHORN, REFERENCE ANTENNA
	12.6	KA5WOT	COM	FEEDHORN
	9.6	KØCQ	HB	LOGARITHMIC DISH FEED
	7.9	WD4FAB	HB	25-TURN HELIX

3456 MHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	28.9	WB9SNR	HB	48-INCH PARABOLIC DISH, DIPOLE FEED
	28.4	WB9SNR	HB	48-INCH PARABOLIC DISH
#	26.6	WA5VJB	HB	12" X 9" X 12" FEEDHORN, REFERENCE ANTENNA
	17.6	KA8EDE	HB	26-INCH PARABOLIC DISH, CIRCULAR FEED
	16.8	NØCIH	HB	36-INCH PARABOLIC DISH, WA3MUX 3-BAND FEED
	15.7	W5ETG	HB	40 ELE. LOOP YAGI
	5.3	KØCQ	HB	LOGARITHMIC DISH FEED
	3.3	N4MW	HB	ALFRED SLOT, W/O COVER
	0.6	N4MW	HB	ALFRED SLOT, WITH COVER

5760 MHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	27.2	KK7B	HB	19-INCH PARABOLIC DISH, DIPOLE FEED
	26.3	KA8EDE	HB	26-INCH PARABOLIC DISH, MODIFIED FEED
#	21.5	WA5VJB	HB	FEEDHORN, REFERENCE ANTENNA
	21.3	KK7B	HB	19-INCH PARABOLIC DISH, JUICE CAN FEED

10 GHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	43.4	WD4MUO	HB	72-INCH PARABOLIC DISH, MOUNTED IN TRUCK BED
	31.0	WD4MUO	HB	18-INCH PARABOLIC DISH, FLAT REFLECTOR FEED
	30.9	KA8EDE	HB	26-INCH PARABOLIC DISH, MODIFIED FEED
	26.7	WA5VJB	HB	12-INCH PARABOLIC DISH, BACKSPLASH FEED
	24.0	WD4MUO	COM	FEEDHORN
	22.1	KK7B	HB	19-INCH PARABOLIC DISH, 5760 MHz DIPOLE FEED
#	17.7	WA5VJB	HB	5" X 3" X 6" FEEDHORN, REFERENCE ANTENNA
	9.7	WD4MUO	HB	OMNI SLOT
	7.7	N9LHD	COM	TEST FEEDHORN

24 GHz

	GAIN (dBi)	CALL	COM/HB	DESCRIPTION
*	32.5	WA5VJB	HB	12-INCH PARABOLIC DISH, W2IMU FEED AND BACKSPLASH PLATE
	29.5	WA5VJB	HB	12-INCH PARABOLIC DISH, BACKSPLASH PLATE
#	12.5	WA5VJB	HB	1.5" x 1" x 2" DUAL-MODE FEEDHORN, REFERENCE ANTENNA

25th Central States VHF Society Conference
Preamp Noise Figure/Gain Measurement Results
July 26, 1991 - Cedar Rapids, Iowa

TEST EQUIPMENT CONSISTED OF HP-8970 WITH HP-346A NOISE SOURCE

N/Figure = Noise/Figure * = Indicates Category Winner COM = Commercial HB = Homebrew

50 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.56	34.00	NØUU	HB	MGF1801
0.98	19.50	W9JMS	COM	JANEL
2.74	18.65	NØCIH	HB	MSA0685

144 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.18	25.77	WA5VJB	HB	MGF1801
0.21	19.60	WA5VJB	HB	MGF2116
0.21	17.65	WA5VJB	HB	MGF2116
0.28	21.68	WA8EUU	COM	FSC 11, MICROWAVE COMPONENTS OF MICHIGAN
0.28	20.73	WA8EUU	COM	FSC 11, MICROWAVE COMPONENTS OF MICHIGAN
0.29	20.29	K5MAT	HB	MGF1402
0.42	22.37	AF1T	HB	MGF1402
0.42	21.05	AF9Y	HB	MGF1601
0.42	15.69	WA5VJB	HB	MGF2116
0.46	27.52	W7VXW	HB	MGF1302
0.51	21.95	KB4WM	HB	MGF1302
0.56	20.50	KA8SSB	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.58	20.74	KB4MW	HB	MGF1302
0.58	19.73	AF9Y	HB	MGF1202
0.63	15.87	KR9U	HB	MPD2501
0.69	21.05	KA8SSB	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
1.19	9.80	NØAKC	HB	MGF1302
1.22	20.34	WQØP	COM	MGF1302
1.72	13.48	WQØP	HB	NE25137

220 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.36	19.40	WA5VJB	HB	MGF1801
0.43	22.49	KA8SSB	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.50	17.67	KCØP	HB	ALF3003
0.73	19.05	NØCIH	HB	NE25137
0.83	20.65	NØCIH	HB	NE25137, WA5VJB DESIGN

432 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.29	24.15	KB4MW	HB	MGF1302, CAVITY
0.35	21.90	KØDAS	HB	MGF1302, WA7CJO CAVITY DESIGN
0.38	18.80	WØRAP	HB	MGF1302, VARIABLE LENGTH CAVITY
0.39	18.50	KB4MW	HB	MGF1302, CAVITY
0.40	15.45	NØCIH	HB	MGF1302, WA7CJO CAVITY DESIGN
0.43	20.45	K9ZZH	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.45	23.15	K9UIF	HB	MGF1200
0.45	19.35	WA9FWD	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.47	18.56	NØJCF	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.49	18.46	K5JL	HB	MGF1302
0.50	17.87	W8TN	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.52	20.10	W4ODW	HB	MGF1302/NE25137
0.55	20.15	WA9FWD	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.56	17.38	WA9FWD	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.56	16.75	K9ZZH	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.57	21.72	N8BXP	HB	MGF1302
0.59	20.57	KA8SSB	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.67	21.78	WQØP	HB	NE25137
0.69	17.20	WDØFCH	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.71	19.93	N8BXP	HB	MGF1302

432 MHz (Continued)

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
0.74	16.15	K9UIF	HB	MGF1402
1.20	22.60	NØCIH	HB	NE41137, WA5VJB DESIGN
1.25	14.93	WA9HUV	HB	MGF1200
1.69	14.86	WQØP	COM	MRF911
2.78	13.60	WQØP	COM	MRF911
9.53	1.40	AA6WI	COM	MGF1302

902 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.41	21.09	W4ODW	HB	NE72089
0.42	18.50	AF1T	HB	MGF1302
0.44	14.45	WØRAP	HB	MGF1302, WØRAP CAVITY DESIGN
0.60	16.75	AF1T	HB	NE21889
0.65	13.45	NØCIH	HB	MGF1302, CAVITY
0.69	18.60	KA8EDE	HB	UNKNOWN DEVICE
2.02	27.05	NØCIH	HB	MGF1302, TRANSVERTER

1296 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
0.58	14.97	WA9FWD	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
* 0.58	14.57	N8BXP	HB	MGF1302
0.63	14.13	K9UIF	HB	WA8JK DESIGN
0.65	15.71	KAØIAB	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
0.74	17.19	WA9FWD	HB	WB8BKC DESIGN
0.79	16.30	AA6WI	COM	MGF1302, DOWNEAST MICROWAVE
0.93	13.65	WA6MGZ	COM	MGF1302, MICROWAVE COMPONENTS OF MICHIGAN
1.79	2.21	WA5VJB	HB	VARACTOR, PARAMETRIC AMPLIFIER
5.80	11.27	WA9FWD	COM	UNKNOWN DEVICE, AVANTEK
9.50	1.40	AA6WI	COM	MGF1302, DOWNEAST MICROWAVE

2304 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 0.60	17.08	WB5LUA	HB	ATF35076
0.60	14.60	WB5LUA	HB	ATF10135
0.78	13.45	W4HHK	HB	ATF10135
0.80	13.70	W3HQT	COM	ATF20135, DOWNEAST MICROWAVE
0.83	12.45	W3HQT	COM	ATF10135, DOWNEAST MICROWAVE

3456 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
No Entries				

5760 MHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
No Entries				

10 GHz

N/Figure	GAIN (dB)	CALL	COM/HB	DESCRIPTION
* 1.13	11.13	WB5LUA	HB	ATF35076
1.45	14.57	WA5VJB	HB	FHX04
1.92	19.35	WB5LUA	HB	DUAL ATF13135
1.98	8.68	WB5LUA	HB	ATF13135
6.54	13.87	WA5VJB	COM	TELEDYNE
8.72	27.38	WA5VJB	COM	TUNNEL DIODES

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1992 INTERNATIONAL 6 METER BEACON LIST

****

PUBLISHED BY: HARRY SCHOOLS KA3B, 1606 S. NEWKIRK ST., PHILADELPHIA, PA. 19145 USA

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The International 6 Meter Beacon List is published once a year as a service to 50 MHz enthusiasts worldwide. This listing may be quoted or reprinted provided that credit is given. A copy of this list can be obtained by sending $5.00 in U.S. funds payable to: Harry Schools. This fee must be charged to cover the costs of printing & mailing.

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1992 marks the sixth year of the International 6 Meter Beacon List. When the very first listing was published in 1987 there were well under a hundred beacons active on 50 MHz. By virtue of the 6 meter band becoming a truly worldwide allocation and the increased interest and study of VHF propagation, this year's compilation boasts an impressive 141 beacons with more being added with each passing month. The bad news however, is that clear frequencies are becoming more and more difficult to coordinate, especially within the narrow 50.060 - 50.080 Mhz beacon sub-band for unattended beacons in the United States. Additionally, the Caribbean area is in dire need of a well-situated 50-100 watt beacon utilizing omni-directional polarization. As an example, the FY7THF beacon in French Guiana at 100 watts to a ground plane antenna has proved worthy over the years as being one of the most strategically located beacons in the world. Unfortunately, it is located too far south from the Caribbean theatre to act as an adequate warning device for openings in this area. I have been told that the 6Y5RC beacon in Jamaica may be resurrected very soon, if not already. This would be most welcome news.

Each year there are deletions and this year is no exception. Beacons removed from the 1992 list are: H44HIR 50.005, JD1ADP 50.012, OX3VHF 50.045.6, N6CW 50.070, N5JM 50.077, ZS4SA 50.073, K5ZXE 50.075.5, WB2CUS/2 50.077, VE2STL 50.086, KG6DX 50.100, and 4S7EA 50.120. In brief, H44HIR was last QRV 6-90, JD1ADP is QRT more than QRV, OX3VHF has been having its share of problems and for the last year was QRT much of the time, N6CW is QRT, N5JM is QRT due to RFI getting into cordless phones operating at 49 MHz, ZS4SA is QRT, K5ZXE is QRT, WB2CUS (the NY beacon) is QRT, VE2STL is QRT due to RFI problems and a lapsed license, KG6DX was QRT more than QRV, and 4S7EA was never reported.

Some of the new beacons added to the 1992 list are: XE2HWB 50.008, DX1HB 50.008, HIØVHF 50.008, 4N3SIX 50.014, CU3URA 50.014, PJ4B 50.015, V73AT 50.036.6, JA7YYL 50.048, VK3SIX 50.053.5, JA5FFJ 50.054, VE2TWO 50.055, KH3AF 50.063.5, GB3LER 50.064, KA5FYI 50.066.5, KK4M/7 50.070, W2CAP/1 50.070, WB9STR 50.071.5, WA4IOB 50.075, 3D2FJ 50.084.2, PY5XX 50.095, JH8ZND 50.480, and VK4RBM 52.445. Also, many of the beacons which appeared in the 1991 list have had changes made to their operating parameters whether it be higher power or a new antenna system.

Just as this listing was going to print, I received word of several new (and planned) beacons such as: VE6MTR 50.032.8, UL8GDD 50.035.5, VE7BEE 50.049.9, VE5US 50.063.5, VE1MQ 50.088, PJ2SIX 50.094, XE3WMA 50.100, OD5SIX 50.078, CN6VHF, YS1YS and others! If any of these stations prove to be legitimate beacons during the course of 1992, they will appear (with full details) in the 1993 list.

As mentioned earlier there are 141 beacons represented in this listing. About ten of these beacons did not have survey forms prepared because I was unable to locate the operator/custodian. Of the 131 survey forms which were mailed out, 42 operators and custodians did not respond to the survey. Therefore, the information presented on these particular beacons is from 1991 (or before) and may not be accurate. For some reason unbeknownst to me, the majority of hold-outs are from Australia (VK). Also, I will continue to refrain from listing stations who have been known to run keyers from time to time. The purpose of this publication is to list stations which are truly "beacons" with a signal being transmitted 24 hours a day or close to it, even if it is on a seasonal basis. It's difficult enough trying to keep track of legitimate beacon stations let alone individual station operators who decide to run their keyers whenever they feel like it. See you on 6! DE KA3B 1 MAY 1992

1992 INTERNATIONAL 6 METER BEACON LIST

50.000 **GB3BUX** **IO93 CW C** Buxton, England
TRANSMITTER: Solid State (modified PMR unit) @ 15 watts
ANTENNA: Single turnstile @ 7m AGL / 450m ASL
MESSAGE: **"GB3BUX IO93BF"**
REPORTS TO: Dr. A.J.T. Whitaker G3RKL, 160 Derbyshire Lane, Sheffield, South Yorkshire, England S8 8SE
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.005 **ZS2SIX** **KF25 FSK C** Republic of South Africa
TRANSMITTER: Unknown type @ 25 watts
ANTENNA: Dipole oriented North/South
MESSAGE: Exact text unknown
REPORTS TO: South African Radio League, Box 3911, Cape Town 8000, Republic of South Africa
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.007.5 **KØGUV** **EN26 CW C** Park Rapids, Minnesota
TRANSMITTER: Harvey Wells @ 18 watts
ANTENNA: Halo @ 40 feet AGL
MESSAGE: **"- - - - - DE KØGUV/KØGUV BEACON IN MINNESOTA - - - -"**
REPORTS TO: Edward DeLa Hunt Jr. KØGUV, P.O. Box 49, Park Rapids, Minnesota 56470
NOTE: The KØGUV Beacon is attended for 24 hours, hence the 50.007.5 operating frequency.

50.008 **XE2HWB** **DL44 CW C** La Paz, Baja California, Mexico
TRANSMITTER: Homebrew by N6CA/N6XQ @ 1 watt
ANTENNA: Quad loop at 21 feet AGL
MESSAGE: **"HOLA DE XE2HWB/B DL44 LA PAZ"**
REPORTS TO: Lucano Bernardo Gonzalez Maldonado XE2HWB, P.O. Box 674, La Paz, Baja California Sur, 23000 Mexico

50.008 **DX1HB** **PK04 CW C** Manila, Philippines
TRANSMITTER: Unknown type @ 20 watts
ANTENNA: J-pole @ 80' AGL
MESSAGE: **"DE DX1HB/B PK04 (string of dashes)"**
REPORTS TO: Unknown at this time.
NOTE: This station did not respond to the 1992 Beacon Survey The data listed may not be accurate.

50.008 **HIØVHF** **FK58 CW C** Dominican Republic
TRANSMITTER: Unknown
ANTENNA: Unknown
MESSAGE: Unknown
REPORTS TO: Unknown
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.010 **JA2IGY** **PM84 CW C** Mount Asama, Mie, Japan
TRANSMITTER: Icom IC575 @ 10 watts
ANTENNA: Comet CA350 Ground Plane (height unknown)
MESSAGE: **"V V V DE JA2IGY"**
REPORTS TO: Via JARL

50.014 **4N3SIX** **JN76 CW C** Domzale, Slovenia
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: 5 element yagi @ 15m AGL / 305m ASL
MESSAGE: **"4N3SIX SLOVENIA JN76HD (LONG DASH)"**
REPORTS TO: YU3GO (Beacon custodian)
NOTE: This beacon will be moved in the near future to Mount Kum which is 1220m ASL.

50.014 **CU3URA** **HM68 CW C** Azores Islands
TRANSMITTER: Homebrew by N4LTA @ 5 watts
ANTENNA: M2 6M Sqloop (height unknown)
MESSAGE: **"CU3URA/SIX HM68"**
REPORTS TO: Unknown at this time.

1992 INTERNATIONAL 6 METER BEACON LIST

50.015 **PJ4B** **FK52 FSK C** Bonaire, Netherland Antilles
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: 1/2 wave vertical @ 45 feet AGL
MESSAGE: **"PJ4B FK52TF BCN"**
REPORTS TO: Chet Brandon PJ9EE, P.O. Box 298, Bonaire, Neth. Antilles

50.015 **SZ2DH** **KM27 FSK C** Athens, Greece
TRANSMITTER: Homebrew @ 5 watts
ANTENNA: 4 element yagi @ 10m AGL/25m ASL (beaming east)
MESSAGE: **"DE SZ2DH KM27AW 10W ERP"**
REPORTS TO: Dr. C.G. Fimerelis SV1DH, 23 Elianou Str, Athens 112-54, Greece
NOTE: The SZ2DH Beacon is located near Athens and operates 24 hours a day except when SV1DH is QRV from this QTH.

50.017 **JA6YBR** **PM51 CW C** Miyazaki, Japan
TRANSMITTER: Homebrew @ 50 watts
ANTENNA: Turnstile Hentenna @ 20m AGL
MESSAGE: **"VVV VVV VVV DE JA6YBR MIYAZAKI PM51RT A"** sent at 50 watts, then the letter **"U"** at 10 watts, then the letter **"V"** at 1 watt, then the number **"4"** at 0.1 watt. (A more extensive message is sent twice per hour).
REPORTS TO: Miyazaki University ARC, Nishi 1-1 Gakuenkibanadai, Miyazaki City, 889-21, Japan
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.018 **V51VHF** **JG87 FSK C** Windhoek, Namibia
TRANSMITTER: GE Master II @ 60 watts
ANTENNA: 5/8 wave vertical @ 6000 feet ASL
MESSAGE: **"LOC JG87 DE V51VHF"**
REPORTS TO: D. Moore V51DM, P.O. Box 22951, Windhoek 9000, Namibia

50.019.9 **P29BPL** **QI30 CW I** Papua New Guinea
TRANSMITTER: Unknown type @ 20 watts
ANTENNA: Turnstile (height unknown)
MESSAGE: **"P29BPL"**
REPORTS TO: Paul Linsley P29PL, PNG Elcom, Box 559, Badili, NCD, Papua New Guinea
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.020 **CX1CCC** **GF15 CW C** Montevideo, Uruguay
TRANSMITTER: Unknown type @ 5 watts
ANTENNA: Ground Plane (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Centro Radio Aficionados Montevideo, P.O. Box 6000, CP 11000 Montevideo, Uruguay

50.020 **GB3SIX** **IO73 FSK C** Anglesey, Wales
TRANSMITTER: Modified Pye comercial solid state unit @ 100 watts
ANTENNA: 3 element yagi beaming 270° @ 58m ASL
MESSAGE: **"GB3SIX IO73TJ"**
REPORTS TO: A.M. Mills GW3NNF, Hafod Onnen, Amlwch, Anglesey, Gwynedd, Wales LL66 OAN
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.021 **OZ7IGY** **JO55 CW C** Tollose, Denmark
TRANSMITTER: Homebrew @ 30 watts
ANTENNA: Turnstile @ 105m ASL
MESSAGE: **"OZ7IGY"** every 40 seconds. **"A"**, **"E"**, or **"T"** can be added for propagation warnings (Aurora, E-skip, or Tropo)
REPORTS TO: Ivan Gyllich Stauning OZ7IS, Bartholinstraede 20, Vridslosemagle, DK-2630 Tastrup, Denmark
NOTE: OZ7IGY is sponsored by the EDR (Experimenterende Danske Radioamatorer).

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50.021.5 **FR5SIX** LG78 CW C — Reunion Island
TRANSMITTER: Homebrew by F5QT @ 2 watts
ANTENNA: Halo near the top of the mountain "Le Piton de Neige" @ 2,970m ASL
MESSAGE: **"FR5SIX LG58"**
REPORTS TO: Hoarau Michel FR5EL, BP87, Le Tampon-Cedex, 97832, Ile de la Reunion
NOTE: The FR5SIX Beacon transmits the grid square "LG58" which is incorrect.

50.024.5 **ZP5AA** GG14 CW C — Caacupe, Paraguay
TRANSMITTER: Homebrew by N4LTA @ 5 watts
ANTENNA: Dipole (height unknown)
MESSAGE: **"ZP ZP ZP ZP5AA GG14"**
REPORTS TO: Radio Club of Paraguay, P.O. Box 512, Asuncion, Paraguay

50.025 **OH1SIX** KP11 CW C — Ikaalinen, Finland
TRANSMITTER: Homebrew @ 50 watts
ANTENNA: Horizontal stacked X-dipoles @ 33m AGL
MESSAGE: **"DE OH1SIX IN KP11QU (10 second dash)"**
REPORTS TO: RATS/OH1SIX, PL 88, SF-02151 Espoo, Finland (Custodian is OH3BK)

50.025.5 **9H1SIX** JM75 FSK C — Attard, Malta
TRANSMITTER: UKSMG homebrew @ 7 watts
ANTENNA: Ground plane @ 300 feet ASL
MESSAGE: **"9H1SIX JM75FV"**
REPORTS TO: Philip Aquilina 9H1PA, Flamingo, Triq Ruzar Briffa, Mosta, MST-03, Malta

50.026 **YV4AB** FK50 CW C — Valencia, Venezuela
TRANSMITTER: Homebrew @ 15 watts
ANTENNA: Cushcraft AR-6 Ringo @ 50 feet AGL/4,500 feet ASL
MESSAGE: **"DE YV4AB"**
REPORTS TO: Ivan Aguirreche YV4AB, P.O. Box 1717, Valencia, Venezuela

50.027 **ZS6PW** KG44 FSK I — Republic of South Africa
TRANSMITTER: Unknown type/power unknown
ANTENNA: Yagi (unknown type) beaming North
MESSAGE: Exact text unknown
REPORTS TO: F. Anderson ZS6PW, 101 van Niekerk St, Meyers Park 0184, Republic of South Africa
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.027 **JA7ZMA** QM07 CW C — Fukushima, Japan
TRANSMITTER: Unknown type @ 50 watts
ANTENNA: 6 element beam @ 15m AGL/500m ASL beaming South
MESSAGE: **"VVV DE JA7ZMA JA7ZMA JA7ZMA QM07"**
REPORTS TO: Kinya Honda JH7DHS, 110 Aza Nagura, Yoshikura, Fukushima, Fukushima 960, Japan
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.030 **CTØWW** IN61 FSK C — S. Joao Pesqueira, Portugal
TRANSMITTER: Homebrew solid state @ 40 watts
ANTENNA: Omni-directional dipole @ 700m ASL
MESSAGE: **"CTØWW IN61GE (dash)"**
REPORTS TO: Tiago Frederico CT1WW, Nagoselo do Douro, 5130 S. Joao Pesqueira, Portugal

50.032.5 **ZD8VHF** II22 FSK C — Ascension Island
TRANSMITTER: Homebrew by G3JVL @ 40 watts
ANTENNA: 5/8 wave vertical @ 2,350 feet ASL on Green Mountain
MESSAGE: **"ZD8VHF AAAA ZD8VHF AAAA ZD8VHF AAAA ZD8VHF ASCENSION ISLAND II22TB"**
REPORTS TO: Unknown at this time.
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

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50.033.8 **LU8YYO** **FF50 CW C** Neuquen, Argentina
TRANSMITTER: Unknown type @ 10 watts
ANTENNA: 1/2 wave vertical @ 30m AGL
MESSAGE: **"..DE LU8YYO...DE LU8YYO..."**
REPORTS TO: Victor Ahualli LU8YYO, Box 628, 8300 Neuquen, Argentina

50.035 **ZB2VHF** **IM76 FSK C** Gibraltar
TRANSMITTER: Homebrew @ 30 watts
ANTENNA: 1/4 wave Ground plane/5 element yagi (height unknown)
MESSAGE: **"ZB2VHF GIBRALTAR IM76HE G G G G G G"**
REPORTS TO: J. Bruzon ZB2BL, 1 Willis's House, Calpe Road, Gibraltar
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.036.6 **V73AT** **RJ38 CW C** Marshall Islands
TRANSMITTER: Homebrew @ 20 watts
ANTENNA: Cushcraft AR-6 Ringo @ 18 feet AGL
MESSAGE: **"DE V73AT/B RJ38"**
REPORTS TO: V73AT

50.038.7 **FY7THF** **GJ35 FSK C** Kourou, French Guiana
TRANSMITTER: Unknown type @ 100 watts
ANTENNA: Ground plane @ 30 feet AGL
MESSAGE: **"FY7THF"**
REPORTS TO: Unknown at this time
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1988 and may not be accurate.

50.040 **VO1ZA** **GN37 FSK C** St. John's, Newfoundland
TRANSMITTER: Homebrew @ 1 watt
ANTENNA: 0.27 wavelength ground plane @ 80 feet AGL/250 feet ASL
MESSAGE: **"VVV DE VO1ZA 47.6N 52.7W AR"**
REPORTS TO: J.D.C. Craig, Box 51, St. John's, Newfoundland, Canada A1C 5H5

50.040 **SV1SIX** **KM17 FSK C** Athens, Greece
TRANSMITTER: Homebrew @ 30 watts
ANTENNA: Vertical dipole @ 30m AGL/100m AGL
MESSAGE: **"SV1SIX SV1SIX SV1SIX LOCATOR KM17VX ATHENS 30W ERP"**
REPORTS TO: Dr. C.G. Fimerelis SV1DH, 23 Elianou Str, Athens, 112-54, Greece

50.042 **GB3MCB** **IO70 FSK C** Cornwall, England
TRANSMITTER: Pye PMR base unit @ 14 watts
ANTENNA: 1/2 wave dipole @ 315m ASL
MESSAGE: Exact text unknown
REPORTS TO: T. Cooper G4XOP, 55 Meadway, Parkway, St. Austell, Cornwall, England PL25 4HT
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.042 **YV5ZZ** **FK60 FSK C** Caracas, Venezuela
TRANSMITTER: Unknown type/Unknown power
ANTENNA: Unknown type/Unknown height
MESSAGE: **"YV5ZZ IN FK70....."**
REPORTS TO: Edgar Mueller YV5ZZ, Box 76093, Caracas DF, Venezuela
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.043 **ZL3MHF** **RE66 CW C** Christchurch, New Zealand
TRANSMITTER: Homebrew @ 20 watts
ANTENNA: (2) 2-element end-fire arrays @ 110m ASL
MESSAGE: **"ZL3MHF (dash) ZL3MHF (dash) NE (dash) NE (dash)"** on the NE beam, then... **"ZL3MHF (dash) ZL3MHF (dash) NW (dash) NW (dash)"** on the NW beam.
REPORTS TO: R.D. Johnson, 189 Queensburg Street, Christchurch 8006, New Zealand

1992 INTERNATIONAL 6 METER BEACON LIST

50.044.6 **JR6YAG** — **PL36 CW I** — Kadena, Okinawa
TRANSMITTER: Icom IC551D @ 20 watts
ANTENNA: 5/8 wave ground plane @ 20m AGL
MESSAGE: **"VVV DE JR6YAG OKINAWA PL36"**
REPORTS TO: Ryuku Radio Club, C/O Kenji Chibana, 463 Kadena, Okinawa, Japan

50.045 **JD1BFI** — **QL17 CW I** — Chichijima, Ogasawara
TRANSMITTER: Yaesu FT625RD @ 5 watts
ANTENNA: 8 element yagi (or) 2 element HB9CV @ 15m AGL
MESSAGE: **"VVV VVV DE JD1BFI JD1BFI JD1BFI QL17FB IN OGASAWARA"**
REPORTS TO: Hiroyoshi Sugiwa JD1BFI, Ogasawara Marine Ranch, Chichijima, Ogasawara, Tokyo 100-21, Japan

50.046 **VK8RAS** — **PG66 FSK C** — Alice Springs, Australia
TRANSMITTER: Unknown type @ 15 watts
ANTENNA: Two (2) horizontal crossed dipoles
MESSAGE: **"VK8RAS"** repeated every 15 seconds
REPORTS TO: Beacon Officer, P.O. Box 2953, Alice Springs, Northern Territory, Australia 0871 (Custodian is VK8ZLX)
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.048 **JA7YYL** — **QM08 CW C** — Iwate, Japan
TRANSMITTER: Unknown type @ 1 watt
ANTENNA: Ground plane (height unknown)
MESSAGE: **"VVV DE JA7YYL 1 WATT QM08OW"**
REPORTS TO: Nec Tohoku ARC, 1 Karakai, Ichinoseki, Iwate 021, Japan
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.050 **GB3NHQ** — **IO91 FSK C** — Potters Bar, England
TRANSMITTER: Pye unit @ 15 watts
ANTENNA: Crossed dipoles @ 35m ASL
MESSAGE: "(8 second carrier, then 16 second message of): **GB3NHQ IO91VQ"**
REPORTS TO: RSGB HQ, Lambda House, Cranbourne Road, Potters Bar, Hertfordshire, England EN6 3JE

50.050 **FO5DR** — **BH52 CW I** — Mahina, Tahiti
TRANSMITTER: Micor/Motorola @ 50 watts
ANTENNA: Vertical dipole @ 6m AGL
MESSAGE: **"VVV DE FO5DR/B"** (3) times, then **"BH52"**
REPORTS TO: Rene Delamare FO5DR, Box 11078, Mahina, Tahiti, French Polynesia
NOTE: The FO5DR Beacon usually operates from 1700-0500 UTC daily.

50.050 **VE7SIX** — **DN09 CW C** — Kaleden, British Columbia
TRANSMITTER: Icom IC551 w/Lunar amplifier @ 130 watts
ANTENNA: Swiss Quad @ 60 feet AGL
MESSAGE: **"BEACON DE VE7SIX DN09 DN09"**
REPORTS TO: A. Tucker VE7SIX, Box 3, Kaleden, British Columbia, Canada VOH 1KO
NOTE: The VE7SIX Beacon antenna rotates 15° each minute and then returns through 360°. The beacon ID is transmitted every minute on the minute.

50.050 **ZS6DN** — **KG44 AM C** — Pretoria, Rep. of South Africa
TRANSMITTER: Modified mobile transmitter and valve PA @ 100 watts
ANTENNA: 5 element yagi @ 6m AGL pointed Southeast
MESSAGE: **"ZS6DN/B"** every 10 minutes
REPORTS TO: D. Larsen ZS6DN, P.O. Box 109, Irene 1675, Republic of South Africa
NOTE: The ZS6DN Beacon operates on LOW LEVEL AMPLITUDE MODULATION.

50.051 **LA7SIX** — **JP99 CW C** — Tromso, Norway
TRANSMITTER: Modified 40 MHz unit @ 20 watts
ANTENNA: 4 element yagi beaming 190° @ 8m AGL
MESSAGE: **"LA7SIX IN JP99LO"**(80 SECOND CARRIER)
REPORTS TO: Tromso Radio Club, ATTN: LAØBY, P.O. Box 438 N-9001 Tromso, Norway

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50.053.5 **VK3SIX** **QF02 CW C** Wannon Town, Victoria, Australia
TRANSMITTER: Icom IC6A w/Nagra amplifier @ 10/100 watts switched
ANTENNA: 1/4 wave ground plane/9 element M2 yagi @ 40m AGL/300m AMSL
MESSAGE: **"VK3SIX QF02"** repeated every 30 seconds
REPORTS TO: Steve Gregory VK3OT, P.O. Box 622, Hamilton 3300, Victoria, Australia
NOTE: The VK3SIX Beacon is remotely controlled over the VK3RMU UHF Repeater on 438.675 MHz. DTMF tones command the equipment (on/off) by locals. Power can be varied 10/100 watts and the antennas can be switched vertical/horizontal. The 9 element M2 yagi generally points in the direction of anticipated openings (ie: NE to Hawaii from DEC-APR, N to Japan from APR-OCT, and Europe from OCT-JAN. The beacon is located 17km west of Hamilton.

50.054 **JA5FFJ** **PM63 CW I** Kochi, Japan
TRANSMITTER: Yaesu FT620 @ 3 watts
ANTENNA: Yagi beaming 150° @ 10m AGL
MESSAGE: **"VV DE JA5FFJ JA5FFJ"**
REPORTS TO: Takeshi Sawamura, 683 Nishino, Noichi-cho, Kami-gun, Kochi 781-52, Japan
NOTE: The JA5FFJ Beacon usually operates 2200-1000 UTC daily.

50.055 **VE2TWO** **FN08 CW C** Evain, Quebec
TRANSMITTER: Marconi DT87 @ 15 watts
ANTENNA: Horizontal folded dipole facing South @ 1550 feet ASL
MESSAGE: **"VVV DE VE2TWO/BCN FN08 QSL VIA VE2FTR....."**
REPORTS TO: Rene Barbeau VE2FTR, CP 779, Evain, Quebec, Canada JOZ 1YO

50.056 **VK8VF** **PH57 CW C** Darwin, Australia
TRANSMITTER: Homebrew @ 25 watts
ANTENNA: Vertical @ 15m AGL
MESSAGE: **"VK8VF QTH DARWIN PH57 K"**
REPORTS TO: H. Anderson VK8HA, Box 619, Humpty Doo, NT 0836, Australia

50.057 **TF3SIX** **HP94 FSK C** Iceland
TRANSMITTER: Homebrew by G3JVL @ 15 watts
ANTENNA: 5 element yagi (Or) 5/8 wave vertical (heights unknown)
MESSAGE: **"TF3SIX ICELAND HP94CC I I I I I I"**
REPORTS TO: Jakob TF3EJ, Haedarbyggd 25, IS-210 Gardabae, Iceland
NOTE: The TF3SIX Beacon was returned to the UK for repair in June of 1991. As this list is being prepared, the beacon has not yet returned to the air.

50.057 **VK7RSB** **QE37 CW C** Taroona, Australia
TRANSMITTER: Icom IC551D @ 100 watts
ANTENNA: 6 element yagi (or) 5/8 wave ground plane @ 60 feet ASL
MESSAGE: **"VVV DE VK7RSB VK7RSB VK7RSB QE37"** (then 30 second delay)
REPORTS TO: I.G. Kucerans VK7IK, C/O Dept Sea Fisheries, Research Laboratory, Nubeena Cres, Taroona 7053, Tasmania, Australia

50.060 **GB3RMK** **IO77 FSK C** Rosemarkie, Scotland
TRANSMITTER: Modified ITT unit @ 40 watts
ANTENNA: Dipole oriented 0°/180° @ 90 feet AGL/240m ASL
MESSAGE: **"GB3RMK IO77UO (carrier)"** 45 second cycle
REPORTS TO: Chris Tran GM3WOJ, Achnacoille, Lamington, Invergordon, Scotland, UK IV18 0PE

50.060 **K4TQR** **EM63 CW C** Birmingham, Alabama
TRANSMITTER: Micor exiter with amplifier @ 5 watts
ANTENNA: Dipole @ 60 feet AGL
MESSAGE: **"K4TQR/B SOLAR QRP"**
REPORTS TO: Bert Hays K4TQR, 1109 Lay Drive, Birmingham, Alabama 35215

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50.060 **W5VAS** **EM50 CW C** Slidell, Louisiana
TRANSMITTER: VHF Engineering Unit @ 10 watts
ANTENNA: DB-212 vertical @ 310 feet AGL
MESSAGE: **"DE W5VAS BCN NO LA PSE QSL (dash)"**
REPORTS TO: Hank Arsaga W5VAS, 3516 James Drive, Metairie, Louisiana 70003

50.060 **PY1AA** **CW C** Rio de Janeiro, Brazil
TRANSMITTER: Homebrew solid state @ 1.5 watts
ANTENNA: J-pole @ 15 feet AGL
MESSAGE: **"PY1AA (long dash)"**
REPORTS TO: LABRE, Av 13 de Maio, 20 S/2018, 20.013 Rio de Janeiro, RJ Brazil
NOTE: The PY1AA Beacon is located at the QTH of PY1RO. The exact grid locator is not known at this time. PY1RO reports that he may move the beacon frequency up or down slightly as PY2AA is also QRV on 50.060 MHz.

50.060 **PY2AA** **GG66 FSK C** Sao Paulo, Brazil
TRANSMITTER: Homebrew @ 15 watts
ANTENNA: 1/4 wave ground plane vertical in building @ 50m
MESSAGE: **"DE PY2AA LABRE PY2AA"**
REPORTS TO: LABRE, Caixa Postal 22, 01000 Sao Paulo, SP Brazil

50.061 **WBØRMO** **EN10 CW C** Fairbury, Nebraska
TRANSMITTER: Icom IC551D @ 100 watts
ANTENNA: Squalo @ 70 feet AGL
MESSAGE: **"BBB BBB DE WBØRMO/B EN10 NEBR K"**
REPORTS TO: Louie Hanson Jr. WBØRMO, 1321 Elm Street, Fairbury, Nebraska 68352

50.061 **K1NFE** **FN31 CW C** Burlington, Connecticut
TRANSMITTER: Johnson Viking 6&2 @ 15 watts
ANTENNA: Turnstile @ 70 feet AGL / 644 feet ASL (Mine Mountain)
MESSAGE: **"K1NFE BEACON CONN K1NFE/B 06062"**
REPORTS TO: Aniello DePascale K1NFE, Drawer M, pLAINVILLE, Connecticut 06062

50.061.7 **KH6HME** **BK29 CW C** Hawaii
TRANSMITTER: GE Master Progress Line Royal Executive @ 20 watts
ANTENNA: Sloping wire dipole @ 35 feet AGL / 440 feet ASL
MESSAGE: **"ALOHA DE KH6HME/B HAWAII (dash)"**
REPORTS TO: Paul Lieb KH6HME, P.O. Box 511, Pahoa, Hawaii 86778

50.062 **WA8R** **EM79 CW C** Erlanger, Kentucky
TRANSMITTER: Homebrew @ 1 watt
ANTENNA: Halo @ 30 feet AGL
MESSAGE: **"WA8R/B EM79 KY V V V"**
REPORTS TO: Gerald Becker WA8R, 22255 Georgetown Road, Lawrenceburg, Indiana 47025

50.062.5 **GB3NGI** **IO65 FSK C** Londonderry, Northern Ireland
TRANSMITTER: Homebrew @ 25 watts
ANTENNA: Dipole oriented 270°/90° @ 240m ASL
MESSAGE: **"GB3NGI IO65PA (10 second carrier)"**
REPORTS TO: T.A. Doherty GIØOTC, 14 Rodney Street, Portrush, Co. Antrim, Northern Ireland BT56 8LB

50.062.8 **KB6BKN** **CM88 CW I** Novato, California
TRANSMITTER: Icom IC502A @ 3 watts
ANTENNA: Squalo @ 20 feet AGL
MESSAGE: **"DE KB6BKN CM88 DE KB6BKN"**
REPORTS TO: Walt Schivo KB6BKN, 560 Eldridge Avenue, Novato, California 94947
NOTE: The KB6BKN Beacon operates from 1100-1700 UTC daily.

50.063 **W3VD** **FM19 CW C** Laurel, Maryland
TRANSMITTER: Modified tube transmitter @ 10 watts
ANTENNA: Squalo @ 47 feet AGL
MESSAGE: **"DE W3VD/BCN JHU/APL 39.17N 76.9W (dash)"**
REPORTS TO: JHU APL ARC, c/o Jack Colson W3TMZ, John Hopkins Road, Laurel, Maryland 20707

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50.063.5 **KH3AF**

AK56 CW C Johnston Island
TRANSMITTER: Kenwood TS690S @ 15 watts
ANTENNA: Vertical @ 35 feet AGL
MESSAGE: **KH3AF GRID SQ AK56"**
REPORTS TO: Richard D. Giles, P.O. Box 976, APO-AP 96558

50.064 **GB3LER**

IP90 FSK C Lerwick, Shetland Island
TRANSMITTER: Unknown type @ 45 watts
ANTENNA: Dipole (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Andrew Steven GM4IPK, 27 Dalsetter Wynd, Dunrossness, Shetland ZE2 9JJ, UK
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.065 **WØIJR KAØCDN**

DM79 CW C Aurora, Colorado
TRANSMITTER: Icom IC551D @ 20 watts
ANTENNA: Halo @ 30 feet AGL
MESSAGE: **"VVV DE WØIJR DM79 COLO"** is sent for 2 weeks, then **"VVV DE KAØCDN DM79 COLO"** is sent for 2 weeks.
REPORTS TO: Glenn Schultz WØIJR, 15643 East 35th Place, Aurora, Colorado 80011

50.065.5 **GB3IOJ**

IN89 FSK C St. Helier, Jersey
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: G3JVL vertical @ 115m ASL
MESSAGE: **"GB3IOJ IN89WE"**
REPORTS TO: Geoff Brown GJ4ICD, TV Shop, Belmont Road, St. Helier, Jersey, Channel Island

50.066 **VK6RPH**

OF78 CW I Perth, Australia
TRANSMITTER: Phillips FM880 (mod) @ 10 watts
ANTENNA: Omni-directional @ 10m AGL
MESSAGE: **"VK6RPH PERTH"**
REPORTS TO: West Australian VHF Group, P.O. Box 189, Applecross, Western Australia 6153
NOTE: The VK6RPH Beacon operates from the QTH of VK6KRC until a permanent site can be found. The license for "VK6RPR" has been cancelled.

50.066 **WD7Z**

DM24 CW C Yucca, Arizona
TRANSMITTER: Homebrew w/commercial amplifier @ 75 watts
ANTENNA: Squalo @ 60 feet AGL
MESSAGE: **"BBBB DE WD7Z/B DM24 DM24"**
REPORTS TO: David Fuller WD7Z, 1813 Pacific Avenue, Kingman, Arizona 86401

50.066 **WA1OJB**

FN54 CW C Bowdoin, Maine
TRANSMITTER: Homebrew 6146 @ 10 watts
ANTENNA: Coaxial @ 45 feet AGL
MESSAGE: **"WA1OJB/B WA1OJB/B MAINE FN54 PSE QSL"**
REPORTS TO: Robert Glassbrook Jr. WA1OJB, RR #2, Box 3977, Bowdoinham, Maine 04008
NOTE: The WA1OJB Beacon antenna pattern favors Europe.

50.066 **KB5KYB**

EM50 CW C Pascagoula, Mississippi
TRANSMITTER: Homebrew by N4LTA @ 3.5 watts
ANTENNA: Omni-directional @ 70 feet AGL
MESSAGE: **"VVV VVV DE KB5KYB/BCN EM50 MS"**
REPORTS TO: Wynn Dunn KB5KYB, 1106 13th Street, Pascagoula, Mississippi 39567
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.066.5 **KA5FYI**

EM10 CW C Austin, Texas
TRANSMITTER: Homebrew solid state @ 1.5 watts
ANTENNA: 6 element yagi @ 25 feet AGL
MESSAGE: **"DE KA5FYI/B PSE QSL"**
REPORTS TO: Paul Johnston KA5FYI, 207 West Crestland Drive, Austin, Texas 78752

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50.067 **N7DB** **CN85 CW I** Boring, Oregon
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: Halo @ 30 feet AGL
MESSAGE: **"VVV DE N7DB/B ORE CN85 AR"**
REPORTS TO: David Bernhardt N7DB, 15871 SE 322nd Avenue, Boring, Oregon 97009
NOTE: The N7DB Beacon operates during the daytime hours or whenever the band is open.

50.067 **KD4LP** **EM86 CW C** Morristown, Tennessee
TRANSMITTER: Homebrew @ 5 watts
ANTENNA: 1/2 wave vertical @ 4500 feet HAAT (Holston Mountain)
MESSAGE: **"KD4LP/B KD4LP/B KD4LP/B EM86 TN"**
REPORTS TO: James Lee KD4LP, 213 Fuller Estate Circle, Morristown, Tennessee 37813

50.067 **WZ8D** **EM79 CW I** Loveland, Ohio
TRANSMITTER: Icom IC505 @ 6 watts
ANTENNA: 6 element yagi @ 90 feet AGL
MESSAGE: **"WZ8D EM79 OH I I I I"**
REPORTS TO: John Walker WZ8D, 1930 Meredith Drive, Loveland, Ohio 45140-9613
NOTE: The WZ8D Beacon operates primarily in the daytime, especially during the summer months.

50.068.5 **W7US** **DM42 CW C** Mount Lemmon, Arizona
TRANSMITTER: Hamtronics FM board @ 1.5 watts
ANTENNA: Vertical sleeve dipole @ 60 feet AGL/9000 feet MSL
MESSAGE: **"V V V DE W7US/B AZ"**
REPORTS TO: Bill Allen W7US, 11720 E. Twin Hills Trail, Tucson, Arizona 85748

50.068.5 **W4RFR** **EM66 CW C** Nashville, Tennessee
TRANSMITTER: GE Master strip @ 2 watts
ANTENNA: Halo @ 600 feet ASL
MESSAGE: **"VVVV DE W4RFR/B EM66 (10 second carrier)"**
REPORTS TO: Henry Savage W4RFR, Box 864, Fairview, Tennessee 37062

50.069 **K6FV** **CM87 CW C** Woodside, California
TRANSMITTER: Solid state @ 100 watts
ANTENNA: 1 wavelength high corner reflector beaming NE, KLM yagi beaming SW, & twin 5 element yagis beaming NW
MESSAGE: **"QST QST DE K6FV/B IN CM87"**
REPORTS TO: Victor Frank K6FV, 12450 Skyline Blvd, Woodside, California 94062-4541

50.070 **N4MW** **EM55 CW C** Memphis, Tennessee
TRANSMITTER: GE strip @ 250mW w/Mirage amplifier @ 4 watts
ANTENNA: Dipole oriented E/W @ 60m/200 feet AGL
MESSAGE: **"DE N4MW/B EM55 (long dash) AR (long space)"**
REPORTS TO: Dave Meier N4MW, 3205 Covington Pike, Memphis, Tennessee 38128

50.070 **KM4ME** **EM65 CW C** Ovilla, Tennessee
TRANSMITTER: Homebrew w/amplifier @ 10 watts
ANTENNA: Vertical @ 1,200 feet ASL
MESSAGE: **"KM4ME EM65"**
REPORTS TO: Ronald Mott KM4ME, 6965 Waynesboro Hwy, Lawrenceburg, Tennessee 38464

50.070 **KB4UPI** **EM63 CW C** Birmingham, Alabama
TRANSMITTER: Lafayette AM transceiver converted to CW @ 5 watts
ANTENNA: Dipole oriented E/W @ 25 feet AGL
MESSAGE: **"KB4UPI/B EM63 AL 73"**
REPORTS TO: Mick Lindley KB4UPI, 1154 Berkley Road, Birmingham, Alabama 35224

1992 INTERNATIONAL 6 METER BEACON LIST

50.070 **KØHTF** **EN31 CW C** Des Moines, Iowa
TRANSMITTER: Hamtronics T-51 @ 2 watts
ANTENNA: Inverted Vee @ 20 feet AGL
MESSAGE: **"DE KØHTF/BCN IOWA (dash)"**
REPORTS TO: Tom Gruis KØHTF, 1243 48th Street, Des Moines, Iowa 50311-2405

50.070 **N4LTA** **EM94 CW C** Spartanburg, South Carolina
TRANSMITTER: Homebrew (variable) @ 0.1, 1.0 and 10 watts
ANTENNA: 1/2 wave halo @ 50 feet AGL
MESSAGE: **"VVV VVV VVV DE N4LTA/BCN EM94 SC"** (Repeats 3 times), **"VVV VVV VVV DE N4LTA/BCN EM94 SPARTANBURG, SC PSE QSL DIRECT TNX 73"** then the beacon transmits a 10 second tone @ 100 mW, then a 10 second tone @ 1 watt, then a 10 second tone @ 10 watts. After this the beacon repeats the entire sequence. The beacon also runs a series of tone bursts at various power levels (10 dB steps).
REPORTS TO: Pat Bunn N4LTA, Route 11, Springlake Drive, Spartanburg, South Carolina 29302

50.070 **KK4M/7** **DM26 CW C** Las Vegas, Nevada
TRANSMITTER: Homebrew @ 5 watts
ANTENNA: Unknown type @ 35 feet AGL
MESSAGE: **"KK4M/B DM26KC LAS VEGAS, NEVADA, USA PSE QSL RST DE KK4M/B SK"**
REPORTS TO: Marty Hope KK4M, 4379 Hobbs Drive, Las Vegas, Nevada 89120

50.070 **WA7ECY** **CN85 CW I** Troutdale, Oregon
TRANSMITTER: Ameco TX62 @ 10 watts
ANTENNA: Squalo @ 30 feet AGL
MESSAGE: **"DE WA7ECY CN85 K"**
REPORTS TO: Scott MacGregor WA7ECY, 1115 SW 28th Street, Troutdale, Oregon 97060
NOTE: The WA7ECY Beacon will be operational during weekends beginning May 1992.

50.070 **K4AUG** **EM97 CW C** Christiansburg, Virginia
TRANSMITTER: Heathkit Sixer @ 1 watt
ANTENNA: 1/4 wavelength vertical @ 2,200 feet ASL
MESSAGE: Exact text unknown
REPORTS TO: M. Edwards K4AUG, 325 Coal Hollow Road, Christiansburg, Virginia 24073
NOTE: K4AUG retired from the Danville Community College in FM06 (former beacon QTH). The beacon will be QRV from the new EM97 location in the Spring of 1992.

50.070 **W2CAP** **FN41 CW C** Dennis, Massachusetts
TRANSMITTER: Homebrew solid state @ 15 watts
ANTENNA: Vertical folded dipole @ 205 feet AGL
MESSAGE: **"V DE W2CAP/B CAPE COD MASS FN41 X QSL W2CAP/1 X"**
REPORTS TO: Steve Wilson W2CAP/1, 14 Elishas Pond Drive, Yarmouthport, Massachusetts 02675

50.070 **EA3VHF** **JN01 CW C** Spain
TRANSMITTER: Unknown type @ 250 mW
ANTENNA: 5 element yagi @ 15m AGL / 220m ASL beaming NW
MESSAGE: **"EA3VHF JN01"**
REPORTS TO: Jose M. Parramona Mas, Ave Santa Cruz, Menarguens, Lerida, Spain
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.071 **WØVD** **EM27 CW C** Joplin, Missouri
TRANSMITTER: Ameco TX62 @ 10 watts
ANTENNA: 1/4 wave vertical @ 20 feet AGL
MESSAGE: **"WØVD/B EM27RB"**
REPORTS TO: Danny Clevenger WØVD, P.O. Box 183, Carthage, Missouri 64836

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50.071.5 **WB9STR** **EN61 CW C** Bourbonnais, Illinois
TRANSMITTER: Unknown type @ 5 watts
ANTENNA: Turnstile @ 130 feet AGL
MESSAGE: **"WB9STR/B EN61 IL"**
REPORTS TO: Greg Hart WB9STR, P.O. Box 533, Bradley, Illinois 60915

50.072 **KW2T** **FN13 FSK C** Palmyra, New York
TRANSMITTER: Homebrew @ 250 mW
ANTENNA: Squalo @ 150 feet HAAT
MESSAGE: **"DE KW2T/BCN PALMYRA, NY FN13"**
REPORTS TO: Daniel Pedtke KW2T, 1900 Turk Hill Road, Fairport, New York 14450
NOTE: The KW2T Beacon is now SOLAR POWERED. As of May 1992 send reports to: 3755 N. Creek Road, Palmyra, New York 14522.

50.072 **KS2T** **FM29 CW C** Beachwood, New Jersey
TRANSMITTER: GE Master II @ 10 watts
ANTENNA: 1/4 wave vertical @ 180 feet AGL
MESSAGE: **"DE KS2T KS2T KS2T / BEACON / FM29VX FM29VX FM29VX"**
REPORTS TO: Jay Miller KS2T, 527 Woodview Road, Toms River, New Jersey 08755-2153
NOTE: The KS2T Beacon antenna is shared with a repeater, so when the repeater transmits the beacon stops. The repeater is mainly used during morning and afternoon rush hours. When not interupted it's on for 40 seconds and off for 15 seconds.

50.073 **KH6HI** **BL01 CW C** Haleiwa, Hawaii
TRANSMITTER: Yaesu FT680 w/amplifier @ 80 watts
ANTENNA: Turnstile @ 40 feet AGL
MESSAGE: **"VVV DE KH6HI/B QTH BL01 QSX 50.110 ES 28.885"**
REPORTS TO: Bert Ingalls KH6HI, 91-633 Pupu Street, Ewa Beach, Hawaii 96706

50.073 **WB4WTC** **FM06 CW C** Martinsville, Virginia
TRANSMITTER: Icom IC551D @ 10 watts
ANTENNA: (2) 1 wavelength loops @ 90° @ 60 feet AGL/1060 feet MSL
MESSAGE: **"DE WB4WTC/BCN WB4WTC/BCN FM06 FM06 VA VA"**
REPORTS TO: Roger Webb WB4WTC, Box 812, Mount Holly, NC 28120
NOTE: Control operators (trustees) are W4AAH and WB4YJC.

50.074 **WB5DSH** **EM15 CW I** Oklahoma City, Oklahoma
TRANSMITTER: Yaesu FT625RD @ 30 watts
ANTENNA: Halo @ 40 feet AGL
MESSAGE: Exact text unknown
REPORTS TO: Rodney Harrison WB5DSH, 8809 North MacArthur Terrace, Oklahoma City, Oklahoma 73132
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.074 **NN7K** **CN92 CW C** Klamath Falls, Oregon
TRANSMITTER: Lafayette HA650 @ 1 watt
ANTENNA: Vertical dipole @ 15 feet AGL
MESSAGE: **"BEACON DE NN7K CN92 ORE"**
REPORTS TO: Jim Foster Jr. NN7K, P.O. Box 785, Klamath Falls, Oregon 97601
NOTE: The NN7K Beacon is located in an unheated building whereas the frequency will drift depending upon temperature. There is also a distinctive chirp. The frequency can vary between 50.073 - 50.076 MHz.

50.074.5 **VS6SIX** **OL72 CW C** Mount Kellett, Hong Kong
TRANSMITTER: Unknown type @ 10 watts
ANTENNA: 1/2 wave ground plane @450m ASL
MESSAGE: **"DE VS6SIX (dash)"**
REPORTS TO: HARTS, P.O. Box 541, Hong Kong
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

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50.075 **WA4IOB** **EM73 CW C** Snellville, Georgia
TRANSMITTER: Homebrew @ 1.5 watts
ANTENNA: 1/4 wave ground plane @ 30 feet AGL
MESSAGE: **"BBB WA4IOB/EM73"**
REPORTS TO: Gary Bailey WA4IOB, 4245 King Richard Ct, Snellville, Georgia 30278

50.075 **WB4OSN** **EL96 FSK C** Margate, Florida
TRANSMITTER: Motorola MT500 @ 3 watts
ANTENNA: Cushcraft AR-6 Ringo @ 30 feet AGL
MESSAGE: **"DE WB4OSN/B"**
REPORTS TO: Joe Picior WB4OSN, 1485 NW 66 Avenue, Margate, Florida 33063

50.075 **NL7XM/2** **FN30 CW C** Staten Island, New York
TRANSMITTER: Yaesu FT680R w/AEA MM2 keyer @ 1 watt/10 watts
ANTENNA: Radialed vartical @ 15m AGL
MESSAGE: **"NL7XM/2 FN30"**
REPORTS TO: Pete Varounis NL7XM/2, 91 Bryant Avenue 2, Staten Island, New York 10306-2447
NOTE: The NL7XM/2 Beacon operates at 1 watt between 0800-2300 local time and 10 watts from 2300-0800 for 24 hour continuous operation, except when Pete is operating on the band.

50.075.2 **PY2AMI** **GG67 CW C** Sao Paulo, Brazil
TRANSMITTER: Unknown type @ 5 watts
ANTENNA: Ground plane (height unknown)
MESSAGE: **"VVVV DE PY2AMI PWR 5W ANT GP LAT 22 45 S LON 47 16 W LOC GG67IF ALT 600M BOX 31 ZC13470 AMERICANA SP EEEE"**
REPORTS TO: Sub Diretoria Secc LABRE, Box 31, 13470 Americana SP, Brazil
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.075.5 **K7IHZ** **DM43 CW C** Mesa, Arizona
TRANSMITTER: Heathkit HX-10 @ 10 watts
ANTENNA: Squalo @ 70 feet AGL
MESSAGE: **"DE K7IHZ BEACON DM43 SK"**
REPORTS TO: Donald Rutledge K7IHZ, 1876 N. Hamilton Pl, Chandler, Arizona 85225
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.076 **LU1DMA** **FF57 CW C** Mendoza, Argentina
TRANSMITTER: Unknown type @ 10 watts
ANTENNA: 2 element quad (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Antonio Mulis LU1DMA, Box 23, 1836 Llavallol, Buenos Aires, Argentina
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.076.5 **W6SKC** **DM41 CW C** Nogales, Arizona
TRANSMITTER: Yaesu FT620B @ 5 watts
ANTENNA: 2-ring halo @ 10 feet AGL
MESSAGE: **"HI HI HI DE W6SKC/B DM41"**
REPORTS TO: Hank Scharfe W6SKC, P.O. Box 6160, Nogales, Arizona 85628-6160

50.077 **NØLL** **EM09 CW C** Smith Center, Kansas
TRANSMITTER: GLB Kit w/Hamtronics amplifier @ 21 watts
ANTENNA: Stacked halos @ 30 feet AGL and 40 feet AGL
MESSAGE: **"VVV VVV VVV VVV DE NØLL/B"** Once a minute **"KS EM09OW"** is added to the ID
REPORTS TO: Larry Lambert NØLL, 405 Shelton Drive, Smith Center, Kansas 66967

1992 INTERNATIONAL 6 METER BEACON LIST

50.077 **WB2CUS/3** **FN10 CW C** Mount Delano, Pennsylvania
TRANSMITTER: Homebrew @ 1 watt
ANTENNA: Squalo @ 2,100 feet MSL
MESSAGE: **"DE/WB2CUS/3 MT DELANO, PA. FN10 S.A.R.A....."**
REPORTS TO: Dan Petruskewic WB2CUS/3, 53 McKinley Drive, Mount Effort, Pennsylvania 18330

50.077.5 **W8UR** **EN75 CW C** Mackinac Island, Michigan
TRANSMITTER: Yaesu FT620B @ 2 watts
ANTENNA: Dipole @ 900 feet ASL
MESSAGE: **"W8UR/B EN75 PSE QSL"**
REPORTS TO: Dennis Havlena W8UR, Mackinac Island State Park, Box 370, Mackinac Island, Michigan 49757

50.077.5 **VK4BRG** **QG48 CW C** Sarina, Australia
TRANSMITTER: Homebrew @ 3 watts
ANTENNA: Vertical dipole @ 5m AGL / 90m ASL
MESSAGE: **". . . DE VK4BRG"** every 10 seconds
REPORTS TO: Ron Graham VK4BRG, Box 323, Sarina 4737, Australia
NOTE: The VK4BRG Beacon is SOLAR POWERED.

50.078 **PT7BCN** **HI06 CW C** Fortaleza, Brazil
TRANSMITTER: Unknown type @ 5 watts
ANTENNA: Ground plane @ sea level
MESSAGE: **"VV VV DE PT7BCN PWR 5W ANT GP LAT 0345S LONG 3831W LOC HI06RF FORTALEZA, CE"**
REPORTS TO: LABRE, Box 975, 60001 Fortaleza, CE Brazil
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.079.9 **TI2NA** **EJ79 CW C** San Jose, Costa Rica
TRANSMITTER: Homebrew @ 20 watts
ANTENNA: Dipole oriented N/S @ 40 feet AGL
MESSAGE: **"TI2NA TI TI"**
REPORTS TO: Erik Roy TI2NA, Box 661, San Jose 1000, Costa Rica
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

50.080 **WB4OOJ** **EL87 CW C** Tampa, Florida
TRANSMITTER: Solid state @ 12 watts
ANTENNA: Vertical @ 25 feet AGL
MESSAGE: **"VVV DE WB4OOJ/BCN EL87"**
REPORTS TO: Julio Peralta WB4OOJ, 1005 Woodcliff Avenue, Tampa, Florida 33613

50.080 **SK6SIX** **JO57 CW C** Sweden
TRANSMITTER: Unknown type at 1/10 watts
ANTENNA: Ground plane @ 35m ASL
MESSAGE: **"SK6SIX/1W (20 second dash)"** then **"SK6SIX/10W (20 second dash)"** (90 seconds total)
REPORTS TO: Unknown at this time
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.082 **VE1MUF** **FN66 CW I** Doaktown, New Brunswick
TRANSMITTER: Kenwood TS680S @ 1/10 watts
ANTENNA: 5 element yagi @ 60 feet AGL
MESSAGE: **"VVV DE VE1MUF/B FN66"**
REPORTS TO: Via bureau or to: VE1JH, VE1XH, VE1BF
NOTE: The VE1MUF Beacon transmitter belongs to VE1JH. It is QRV during potential E, F2, and AU openings and 24 hours a day during the Es season. The antenna is oriented in the direction of the opening.
*This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

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50.082 **HC8SIX**

EI59 CW C Galapagos Islands
TRANSMITTER: Unknown type @ 4 watts
ANTENNA: 5/8 wave vertical @ 1,800 feet ASL
MESSAGE: **"HC8SIX"**
REPORTS TO: HC8NGR (Address needed)
NOTE: Due to a defective oscillator, the HC8SIX Beacon emits spurs on various frequencies among other things.
*This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.084.2 **3D2FJ**

RH82 CW C Fiji
TRANSMITTER: Homebrew by N4LTA @ 20 watts
ANTENNA: 2-element bi-directional array beaming NNE/SSW
MESSAGE: Exact text unknown
REPORTS TO: Unknown at this time
NOTE: This station did not respond to the 1992 Beacon Survey The information listed may not be accurate.

50.086 **VP2MO**

FK86 CW I Plymouth, Montserrat
TRANSMITTER: Yaesu FT620B @ 10 watts
ANTENNA: 6 element yagi @ 45 feet AGL
MESSAGE: **"VVV VVV DE VP2MO/BCN FK86 MONTSERRAT"**
REPORTS TO: E.B. Martin VP2MO, Box 113, Plymouth, Montserrat
NOTE: The VP2MO Beacon is usually operational from 1300-2300 UTC on Saturday and Sunday and from 1800-2300 UTC on Monday through Friday.

50.086.5 **LU1MA**

FF57 CW C Mendoza, Argentina
TRANSMITTER: Unknown type @ 8 watts
ANTENNA: 1/4 wave ground plane @ 8m AGL
MESSAGE: **"T LU1MA"**
REPORTS TO: Dr. Gerardo S. Ruiz LU8MBL, Godoy Cruz 378, San Jose, 5519 Guaymallen, Mendoza, Argentina

50.091 **9L1SL**

IJ38 FSK C Freetown, Sierra Leone
TRANSMITTER: Homebrew by N4LTA @ 10 watts
ANTENNA: 1/4 wave vertical @ 60 feet AGL
MESSAGE: Exact text unknown
REPORTS TO: Sierra Leone ARS, Box 10, Freetown, Sierra Leone
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.092 **HC2FG**

EI97 CW I Mount Animas, Ecuador
TRANSMITTER: Unknown type @ 50 watts
ANTENNA: J-pole (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Gustavo Falconi Peet HC2FG, P.O. Box 1233, Guayaquil, Ecuador
NOTE: This station did not respond to the 1991 Beacon Survey. The data listed is from 1990 and may not be accurate.

50.095 **PY5XX**

GG54 CW I Matinhos, Brazil
TRANSMITTER: Yaesu FT620B w/Mirage A1015 amplifier @ 50 watts
ANTENNA: Ground plane @ 20m AGL
MESSAGE: **"..... DE PY5XX"**
REPORTS TO: Peter Zoch Sprengel PY5CC, P.O. Box 07, Matinhos, PR 83260 Brazil
NOTE: The PY5XX Beacon is removed from service when PY5CC is QRV.

50.098 **LU2MFO**

FF97 CW C Rosario, Argentina
TRANSMITTER: Unknown type @ 4 watts
ANTENNA: Unknown type (height unknown)
MESSAGE: **"..... DE LU2MFO BEACON DE LU2MFO BEACON QTH ROSARIO PWR 4 WATT 4E 73"**
REPORTS TO: LU2MFO (Address needed)
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

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50.315 **FX4SIX** **JN06 CW C** Neuville de Poitou, France
TRANSMITTER: Homebrew @ 50 watts
ANTENNA: 2 horizontal crossed-dipoles @ 4m AGL/163m ASL
MESSAGE: **"FX4SIX / JN06CQ"**
REPORTS TO: Radio Club Neuvillois FF1OFL, P.O. Box 37, 86170 Neuville de Poitou, France

50.321 **ZS5SIX** **KG50 CW C** Republic of South Africa
TRANSMITTER: Unknown type @ 10 watts
ANTENNA: Halo (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Unknown
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

50.480 **JH8ZND** **QN02 CW C** Chitose, Hokkaido, Japan
TRANSMITTER: Kenwood TS690V @ 10 watts
ANTENNA: Discone @ 10m AGL
MESSAGE: **"VVV DE JH8ZND/B CHITOSE QN02TU"**
REPORTS TO: Yuji Satoh JH8EKJ, 3-8-8 Shintomi, Chitose, Hokkaido 066, Japan
NOTE: The JH8ZND Beacon is scheduled to be relocated by May 1992 to a new site which is 100m ASL.

50.491 **JG1ZGW** **PM95 CW C** Tokyo, Japan
TRANSMITTER: Yaesu FT690R MKII w/HL-166V amplifier @ 10 watts
ANTENNA: Dipole @ 20m AGL
MESSAGE: **"VVV DE JG1ZGW TOKYO PM95UN"**
REPORTS TO: Kazuhiro Yamamoto JJ1PXZ, 19-15 Nakaikegami, 2 Chome, Ohta, Tokyo 146, Japan

50.498 **5B4CY** **KM64 FSK C** Zyghi, Cyprus
TRANSMITTER: Homebrew solid state @ 15 watts
ANTENNA: Ground plane @ 5m AGL
MESSAGE: **"5B4CY"**
REPORTS TO: CARS, P.O. Box 1267, Limassol, Cyprus

50.904 **ZS1STB** **KF05 CW C** Republic of South Africa
TRANSMITTER: Unknown type @ 25 watts
ANTENNA: Ground plane (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: SARL, Box 3911, Cape Town 8000, Rep. of South Africa
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

52.320 **VK6RTT** **OG89 CW C** Wickham, Australia
TRANSMITTER: Unknown type @ 25 watts
ANTENNA: J-pole (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Wickham ARC, P.O. Box 410, Wickham WA6720, Australia
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

52.325 **VK2RHV** **QF57 CW C** Newcastle, Australia
TRANSMITTER: Unknown type @ 10 watts
ANTENNA: Vertical dipole (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: R. Prout, 21 John Street, Dudley Newcastles, NSW 2290, Australia
NOTE: This station did not respond to the 1992 Beacon Survey. The information listed may not be accurate.

52.330 **VK3RGL** **QF22 FSK C** Geelong, Australia
TRANSMITTER: Homebrew @ 20 watts
ANTENNA: Stacked crossed dipoles @ 1,300 feet ASL
MESSAGE: **"DE VK3RGL QF22"**
REPORTS TO: Geelong ARC, P.O. Box 520, Geelong 3220, Australia
NOTE: The VK3RGL Beacon is currently off the air pending modifications and site improvements.

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52.345 **VK4ABP** QG26 FSK C Longreach, Australia
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: Vertical @ 10m AGL
MESSAGE: **"VK4ABP"**
REPORTS TO: Allan Abbott VK4ABP, 33 Quarrian Road, Longreach Q4730, Australia

52.370 **VK7RST** QE37 FSK C Hobart, Tasmania, Australia
TRANSMITTER: Homebrew solid state @ 16 watts
ANTENNA: Dipole oriented N/S @ 130 feet AGL
MESSAGE: **"VK7RST"**
REPORTS TO: RPTR WIA TAS, 105 New Town Road, New Town, Tasmania 7008, Australia

52.420 **VK2RSY** QF56 FSK C Sydney, Australia
TRANSMITTER: Homebrew solid state @ 40 watts
ANTENNA: Crossed dipoles @ 40 feet AGL
MESSAGE: **"VK2RSY LOC QF56MH"** every 30 seconds (Message after callsign changes every couple of weeks).
REPORTS TO: WIA NSW DIV, P.O. Box 1066, Parramatta, NSW 2124, Australia

52.425 **VK2RGB** QF59 FSK C Gunnedah, Australia
TRANSMITTER: Unknown type @ 5 watts
ANTENNA: Omni-directional (height unknown)
MESSAGE: Exact text unknown
REPORTS TO: Gunnedah District, B.J. Harwood Dringle, Gunnedah, NSW 2380, Australia
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1990 and may not be accurate.

52.435 **VK3RMV** QF12 FSK C Hamilton, Australia
TRANSMITTER: Commercial exiter @ 15 watts
ANTENNA: 4 stacked 1/2 wave dipoles @ 300m ASL
MESSAGE: **"VK3RMV"**
REPORTS TO: Steve Gregory VK3OT, Box 662, Hamilton Vic 3300, Australia
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

52.440 **VK4RTL** QH30 CW C Mount St. John, Australia
TRANSMITTER: Homebrew @ 10 watts
ANTENNA: 1/4 wave ground plane @ 25 feet AGL
MESSAGE: **"VK4RTL"**
REPORTS TO: TARC, P.O. Box 964, Townsville 4810, Australia

52.445 **VK4RBM** QG48 FSK C North MacKay, Queensland, Australia
TRANSMITTER: Homebrew @ 7 watts
ANTENNA: 1/4 wave vertical @ 12 feet AGL
MESSAGE: **"VK4RBM"**
REPORTS TO: Richard Barham VK4TFB, P.O. Box 3360, North MacKay, MacKay, Queensland 4740, Australia
NOTE: The VK4RBM Beacon is located at a 2-way commercial site and is SOLAR POWERED. There is currently insufficient power for 24 hour beacon operation. Therefore, the beacon is presently being operated from an office in North MacKay, until such time that changes can be made at the site.

52.445.2 **VK4RIK** QH23 FSK C Mount Haren, Kuranda, Australia
TRANSMITTER: Modified low band commercial unit @ 15 watts
ANTENNA: Dipole @ 490m ASL
MESSAGE: **"VK4RIK"**
REPORTS TO: QLD Tropical VHF Association, Box 5510, Mail Centre, Cairns, QLD 4870, Australia
NOTE: This station did not respond to the 1992 Beacon Survey. The data listed is from 1991 and may not be accurate.

Transatlantic Sporadic-E Notes

And Other Multi-Hop 50-MHz Paths during the Solar Minimum

Emil Pocock, W3EP
625 Exeter Road
Lebanon, Connecticut 06249

Multi-hop sporadic-E is capable of supporting 50-MHz paths of 4400-8800 km under favorable conditions with relatively simple equipment. The eastern US to western European path (5000-6000 km) opens an average of half-a-dozen times each summer season, and even longer distance paths are possible. With world-wide interest in 50 MHz at an all-time high, sporadic-E could sustain interest in the band during the solar minimum.

The anticipated decline of solar cycle 22 by the end of 1992 will surely mean the end of world-wide 50-MHz F_2 propagation until at least the end of the decade, but it does not necessarily mean the end to six-meter DXing. The summer sporadic-E season nearly always produces a number of double-hop events, which provide hundreds of transcontinental and Caribbean contacts for US and Canadian operators up to 4400 km distance each year.[1] Somewhat rarer three-hop sporadic-E contacts up to 6600 km, sufficient for transatlantic contacts from the eastern part of the US and Canada, are also common enough to keep interest in European DX alive each summer season.

There has been enough six-meter transatlantic openings during the past five summer seasons to create a fair idea of the characteristics of this path. Favored dates and times correspond closely to peak times for single-hop sporadic E in North America, after adjusting for the longer distances. Nearly all the openings have taken place during June and July; occurrence may be slightly more probable during the middle of the period. The largest majority of openings have taken place between 1900 and 0000 UTC (centered on about 2130). Significantly fewer openings occur in the morning between 1330 and 1700 UTC (centered about 1500). A compilation of three separate observers, whose collective logs may not provide a complete picture, suggest the path between the eastern US and western Europe opens at least six times during the eight-week summer season.[2] Openings typically span half an hour to several hours at a stretch. See Table 1 for some comparative data from various parts of the US.

Table 1
Transatlantic Sporadic-E Paths

Paris (JN18) to	Distance (km)	Hops	Most Favorable Times (UTC)	
Boston (FN41)	5580	3	1300-1700	1900-0000
Cincinnati (EM79)	6710	3	1330-1730	1930-0030
San Antonio (EL09)	8400	4	1400-1800	2000-0100
Los Angeles (DM04)	9150	5	1500-1900	2200-0100

The northeastern states (within 6000 km of Paris) are favored with greatest share of these openings. See Fig. 1. Stations in the Northeast commonly work the Azores, Portugal, the British Isles, and the Netherlands in approximately that order of frequency. In addition, New Englanders have worked as far east as Italy (at the three-hop limit of 6600 km from Boston), Malta, and Greece (over 7200 km and certainly in four-hop range) on more than one occasion. Central Europe is within three-hops, and four-hop range from Boston extends as far as Turkey, Lebanon, and Israel--three countries just recently authorizing six-meter amateur licenses. With a number of countries in central and eastern Europe also just getting privileges for the band this year, sporadic E holds out a great opportunities from the East Coast.

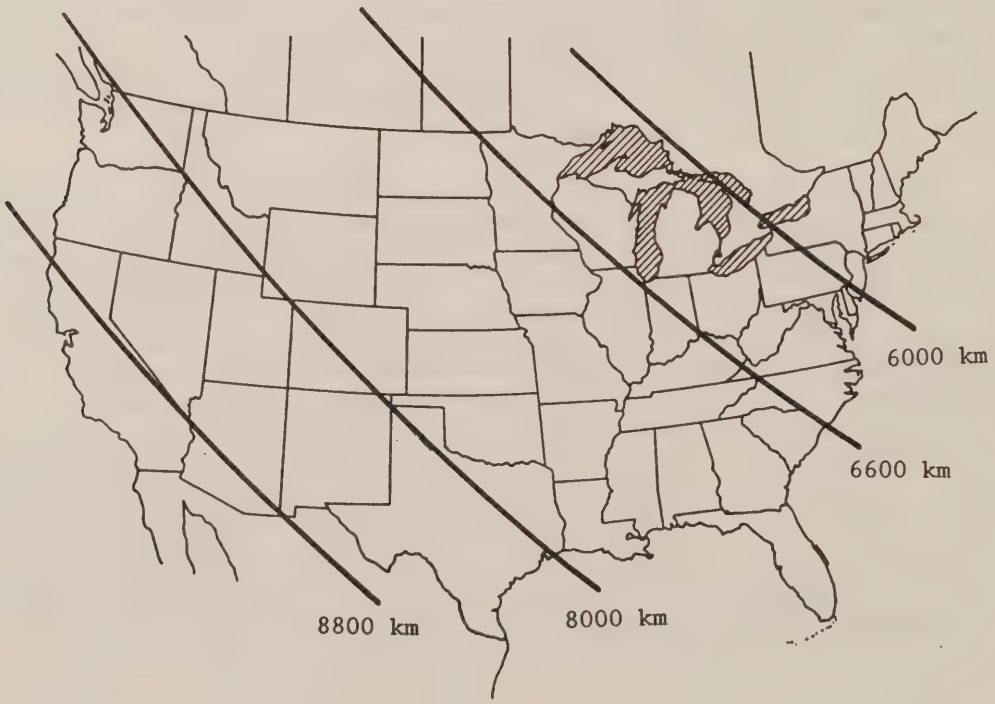

Fig. 1--Distances from Paris, France (JN18)

The central part of the US as far west as New Mexico and Arizona lies within four-hop range (6600-8800 km) of Paris, but even at these distances, Europeans have been worked from time to time. (Some representative paths are included in Table 2.) A far more fruitful ground for working new countries may be the Caribbean and northern part of South America. Indeed, from the central part of the country (EM29), at least 60 countries are within three-hop sporadic-E range (including Scotland and Ireland!) and at least half of those are reachable with two hops. DXCC countries as widely spaced as Iceland (5400 km), Hawaii (5700 km), and Brazil (6300 km) are all within "easy" three-hop range of the central states.

Multi-hop 50-MHz sporadic-E opportunities from the West Coast are somewhat less extensive. Much of the Caribbean is within three-hop distance and undoubtedly this path could be more fully exploited than it has been in the past. The Hawaii-California link is not uncommon via two-hop sporadic E, but the rest of the Pacific islands are at three- and four-hop distances from the West Coast. Alaskans have worked both Japan and the Pacific Northwest, and on rare occasions, the four-hop Japan to Pacific Northwest path has opened.

Table 2
Other Selected Multi-hop Sporadic-E Paths

Path	Distance (km)	Minimum Hops	Estimated Peak Times (UTC)	
Boston (FN41)-Canaries (HM77)	3910	2	1500	2130
Boston (FN41)-Paris (JN18)	5580	3	1430	2100
San Antonio (EL09)-Greenland (GP70)	5240	3	1700	2330
San Antonio (EL09)-Paris (JN18)	8400	4	1600	2120
Los Angeles (DM04)-Boston (FN41)	4220	2	1900	0100
Los Angeles (DM04)-San Juan (FK68)	5410	3	1800	0130
Hawaii (BK29)-San Francisco (CM87)	3685	2	2100	0400
Hawaii (BK29)-Brisbane (QG62)	7660	4	2300	0600
Tokyo (PM95)-Anchorage (BP51)	5660	3	2300	0600
Tokyo (PM95)-Seattle (CN87)	7720	4	2300	0600

It is relatively easy to miss a multi-hop sporadic-E opening because they are so infrequent, especially as there is still no reliable way to forecast when they will take place. Only the broadest dimensions of multi-hop sporadic-E narrow down the possibilities. The overwhelming majority of such events in the northern temperate latitudes (the continental US) take place during June and July. There may be some tendency for events to recur on consecutive days. The favored times center very broadly on 1100 and 1900 UTC local time for path mid-points. Little else can be said with much confidence. The related auroral-E

phenomena, which occur during and just after intense aurora, often support paths up to 4000 km and rarely as long as 6000 km, primarily in higher latitudes. In these cases, the aurora itself will provide some warning.

Probably the most reliable method of catching unusual multi-hop sporadic-E propagation is through some systematic scanning of selected frequencies. European TV video signals in the 48.240-260 MHz range are exceedingly strong and often provide some prior warning of sporadic E. These stations are now primarily in central and eastern Europe, so they may not make entirely satisfactory indicators of conditions from western Europe. Scanning a number of widely scattered 50-MHz European beacons will provide more direct indication of conditions, but it is often the case that low-powered beacons are heard only after contacts have already been made by better-equipped stations.

Notes

1. The normal single-hop sporadic-E range is about 2200 km (1367 miles) and is used as the standard in these notes. Some unusual single-hop contacts may occasionally exceed this distance. It is often impossible to determine precisely how many hops are involved in what are evidently multi-hop sporadic-E paths, because hops may be shorter than 2200 km (especially when the maximum working frequency is much higher than 50 MHz) and hops need not be the same length in a multi-hop series. The minimum number of hops for a given path assume each hop is at the maximum 2200-km distance.

2. Data were derived primarily from the logs of WA1OUB and W3EP/1, and from Kimbell (1986). Thanks Bob.

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(CENTRAL STATES VHF SOCIETY File/VHF Ionospheric Propagation Symposium)
REF: **NEW GENERATION 50 MHz SMART BEACONS**
By: Bob Cooper/ZL4AAA-K6EDX-VP5D et al (15/04/92)

Existing 50 MHz beacons are characterized by two classifications:

1) Those operated principally from a home QTH by a 50 MHz enthusiast, not all of which are active close to 100% of the time;
2) Those operated by clubs or others with mixed or spread operational/maintenance responsibilities, often however at QTHs selected for reasonably good 50 MHz coverage. This class may tend to be operational a higher percentage of the time than the first class.

The sum of both classifications is the present universe of such beacons; approximately 100 in all according to the KA3B (50 MHz Newsletter) list published in the spring of 1991. They are primarily centered in North America and Europe. Because each beacon has been placed on the air as an individual or group effort without real regard to overall 50 MHz objectives, the universe of such beacons tends to approximate the universe of 50 MHz operators by population density. This unfortunately produces a majority of beacons where there is the heaviest concentration of 50 MHz operators, and with rare exceptions (FY7) beacons serve to re-enforce the presence of existing 50 MHz operators rather than being true indicators of unique propagation to a segment of the world where there is little or no activity. At best, many existing beacons tend to 'fill in' those day parts when the universe of 50 MHz operators are not watchful of propagation conditions available.

Existing 50 MHz beacons typically model after their HF counterparts; those found for example within the 28.175-28.305 MHz region on ten meters. The six meter beacons announce their identity, sometimes explain their operating parameters, and 'rest' so as to not tax the duty cycle ability of the transmitter final amplifier or its power supply.

In the ten meter band, where 'band openings' typically last for considerable lengths of time, such an operating approach is perhaps ideal. It is seldom true such beacons are heard for very short periods of time; such as 90 seconds. This is **not** true with 50 MHz beacons and 50 MHz propagation.

The model for existing beacons comes from 1940-ish technology; an underrated final amplifier driven by a reasonably frequency stable oscillator keyed by anything from a 1 rpm motor and etched circuit board 'code wheel' to diodes in a matrix programmed for the message. Few would argue that from scratch it could not be done better, smaller, more energy efficiently today.

THE QUESTION OF BEACON LOCATION:

Starting from ground-zero, there are no beacons. Now, where would you place the first 100 beacons?

FIRST of all, we might ponder all that we **know** or **believe we know** about propagation at 50 MHz. We would analyze the paths which are known to occur, especially those which seem to involve considerable distances with no intermediate 'contacts'; such as 6W1QC to VK4BRG (March 1991 et al around 0030-0200 UTC). Using this path as an example, these two stations found 50 MHz propagation several dozen days in a 60 day period yet on no day did either station find **any sign** of intermediate path signals. This path begs an answer to the question "How did the 50 MHz signals propagate 40% of the way around

the earth and never seem to 'touch down' along the way?". One, two or three beacons could be 'sited' so as to perhaps provide data on this path; data at points intermediate to 6W1 and VK4.

SECOND we could look at the 'outposts' where (typically) island locations fill in vast expanses of ocean; locations which are between continents or regions with significant 50 MHz activity. Here we would be attempting to fill in those voids or holes of wave propagation knowledge by substituting beacons for active 50 MHz stations. ZD8, ZD7 are two such examples in the South Atlantic.

THIRD we would consider the large geographic expanses of the five inhabited continental regions (North America, South America, Africa, Europe and Asia) and using some logical plan site beacons so as to 'matrix' each land mass with at least a representation of beacons.

One approach might be to take the Maidenhead Locator System (ie. Grid Squares) and analyze the make-up of the earth as represented by Maidenhead Locator **Fields.** There are 324 fields, 262 of which have land of some sort, 8 are permanent ice and 54 are only represented by sea. Reference: there are 32,400 separate **1 degree latitude by 2 degrees longitude** 'squares' in the world.

A 50 MHz beacon in **each** Field would be an admireable accomplishment; even in each of the 262 where there is land of some sort. Alas, even if 262 separate beacons could be funded, siting in all 262 land-based Fields would be impossible because of political and radio interference considerations. So if you were establishing an objective, your **real/do-able** number would be something less than 262. Quantity 100 could be a pratical goal for the project. Some might say 100 is **impossible** or **overly ambitious.** Let us not make that assumption, **just yet.**

REDEFINING 'THE BEACON':

Existing beacons 'key-on' for a portion of each time-frame; ie. 30 seconds out of each minute for straight CW, 60 seconds out of each minute for FSK. During their keying sequence, they radiate a signal which may or maynot be heard by a distant observer. If the beacon is logged, we presently depend upon alert and conscientious observers to report they have copied the beacon at a distant point.

During the 1957 IGY (International Geo-Physical Year), an amateur program coordinated by the ARRL and funded by various national agencies enrolled hundreds of 50 MHz amateurs to report in detail their **unusual propagation experiences** at 50 MHz. This data was collected by the IGY program coordinator (Mason Southworth; working out of the ARRL headquarters in Newington, Ct.), collated in sequential time blocks and then forwarded to a group of propagation minded scientists who had signed on for the IGY program. Similar efforts were mounted at two meters (144 MHz), dealing primarily with auroral propagation and coordinated by a German team headed up by DJ2BC. The **IGY Period** was important enough and impressive enough in scientific circles that a number of amateur radio participants were given **special IGY privileges** for the duration of the measurement year. Examples are the 50 MHz permit given to EI2W in Dublin, Ireland and the special 1 kilowatt transmitter power authorized for G5KW on 144 MHz.

Unfortunately, since this 'golden year' there has been no organized effort to collect and collate data relating to 'boundary propagation' (a term given to unusually long distances covered at say 50 or 144 MHz). In the intervening 34 years, amateur radio skills, equipment 'noise floors' and

antenna gain have multiplied dramatically. What was considered noteworthy in 1957 (example: contacting all 6 continents on 50 MHz) can be a one-day event in 1992. The data so eagerly sought in 1957 and collected with such dedication is now available routinely. That's the good news. The sad news is that most of this data goes uncollected, and none but the 'tip of the information iceberg' manages to be recorded for perhaps later study (through the space-limited reporting columns of magazines such as QST or PRACTICAL WIRELESS).

So in 1992 we find ourselves awash in data, uncollected, and perhaps five to ten orders of magnitude more capable of supplying such data than we (the amateur fraternity) were in 1957.

Redoing the 1957 IGY experience might be an exciting prospect but given today's interest in ionospheric propagation (vis-a-vis satellite communications), and the scientific community's almost complete lack of interest in this topic, this is an unlikely prospect.

(The reader is directed to a 1991 publication from the RSGB [1] titled RADIO AURORAS by Charlie Newton, G2FKZ. This book explains with considerable scientific accuracy all that is known or believed about the auroral phenomenon. More importantly, this is a book equal in scientific value to virtually any of the wave propagation books produced by the professional [as opposed to amateur] scientific community. It is noteworthy because this book is entirely the product of amateur communication hobbiests who have voluntarily over 30+ years provided data to an RSGB committee made up of hams just like you and I; people with an intense interest but very little professional training in wave propagation. This book typifies the now all too rare dedication and single minded focus to a unique mystery of wave propagation by a small core group of Amateurs. It serves as an excellent example of the type of effort, and the results of that effort, which might still be assembled from within the Amateur ranks even in this day of 'push button transceivers' and institutionalized licensing.)

[1: RADIO AURORAS, Radio Society of Great Britain, Cranborne Road, Potters Bar, Herts EN6 3JE, England; ISBN 1 872309 03 8; by Charlie Newton, G2FKZ.]

Yet even if there is little residual interest in 'boundary propagation' at the professional scientific level in 1992, the 'probing questions' associated with the 1957 IGY study remain just as unanswered today as they were in 1957. We still:

A) do not understand the Sporadic E mechanism,

B) do not understand F layer propagation at 50 MHz on those dozens (hundreds) of circuits typified by the 6W1QC/VK4BRG contacts.

Clearly, time alone has not solved these mysteries. In truth, with more 50 MHz activity worldwide in 1992, better equipment and more astute operators, we may have more unanswered mysteries 35 years after IGY than we had to justify the 50 MHz IGY project in 1957.

While not a 'cure all' or 'key that will unlock the treasures of boundary wave propagation', a worldwide 50 MHz beacon project using 1990's technology could well go a long way towards uncloaking these mysteries. Perhaps it is time to reinvent the beacon?

THE REINVENTED BEACON:

Amateur entry into space, and parallel developments in Packet communica-

tion technology have shown us that it is no longer necessary for a human being to be 'at the other end' for a QSO to take place.

British (et al) 144 MHz satellites have proven the technology of 'store and forward' data at an amateur level. Russian RS series satellites will answer your call and give you a signal report on 28 MHz. Italian 'robot beacon' IY4M (28.193 MHz) will answer your call, give you a report, and QSL your contact with **nobody home**! And Packet contacts on virtually all of our HF and VHF/UHF bands are routinely conducted between two stations with nobody home at either station.

Clearly the technology for a **smart beacon** exists in amateurdom.

This is the beacon system as presently envisioned:

A) An conceptual goal of 100 such beacons with a 'Phase One' plateau of perhaps 25 as explained here, each virtually identical in design, 'manufactured' by a volunteer amateur club or national society following a design competition conducted worldwide.

B) The placement of these beacon stations by and through local, regional and national radio societies wherein the responsibility for the correct installation, maintenance, and occasional 'dumping' of recorded data is assigned.

1) The siting of the beacons at appropriately chosen points after all available evidence of 50-100 MHz propagation is analyzed and collated.

C) The possible frequency assignment of the beacons based upon appropriate use (and re-use) of the CW sub-band 50.010 to 50.090 MHz.

D) The conversion, where pratical and acceptable, of all existing beacons to the new 'world format'.

E) The creation of a standard beacon message and operating format.

1) Each beacon would transmit for a portion of each time unit (ie. minute) and the time segment would be widely publicized and on-site resettable in the event of power failure or equipment malfunction.

A) Time segment coordination along with frequency coordination would be a part of the 'world format' plan for the project; ie. stations in nearby grid Fields would be assigned operating frequencies and operating time segments to reduce or eliminate unwanted interference or mis-identification at distant points.

F) In addition to transmitting a unique identifier, operating on a unique frequency within a unique time segment, each beacon would also be '**smart**'. Ie:

1) A beacon package would consist of a power source, standardized antenna, and beacon-duty-rated solid state transmitter. **And,**

2) A narrow banded receiver on the same frequency as its transmitter.

3) Each '**site**' would by standardization accept '**calls**' for a portion of its time unit. Like the IY4M ten meter 'robot beacon' or the RS series satellites, a call received above an established sensitivity threshold at the standardized CW speed and spacing would be 'logged' and 'stored' by the **smart beacon**.

An example:

A) Beacon: CU3URA located on Terceira Island, Azores on 50.013

B) The beacon is assigned to transmit from 00:00 to 00:30 each minute.

C) The standard text is:
. . . . . (dits for 03 seconds at 12 WPM, followed by)
032892 (the current UTC date in sequential numbers at 12 words per minute)
/1411 (slash bar; the current UTC time in sequential numbers at 12 WPM)
de CU3URA HM68 K (character space, the identifier with grid square field and end of message indicator; at 12 WPM).

This works out to 30 seconds of transmit time or 50% duty cycle. The full text looks like this:

```
Text:    ..........032892/1411 de CU3URA HM68 K
Seconds: 1         03    09    15        25   30
```

Now, to this point we have what seems like a standard **not-smart** beacon. Along comes PY5CC who hears CU3URA. He tunes in the signal and then 05 seconds after he hears 'K' he transmits just his callsign (PY5CC) at 12 WPM. Assuming conditions are good enough, the beacon (now in the receive mode) hears PY5CC on CW, determines the speed is within its **read window** and like IY4M it logs the call.

The next transmission sequence for CU3URA is different. It is:
... (for three seconds) PY5CC 032892/1411 de CU3URA HM68 K

That's the **semi-smart** part. Once a call has been logged, the beacon repeats the above transmission for a standardized period of time (ie. 3 seconds of dits PY5CC 032892/1411 de CU3URA HM68 K) such as 05 minutes. In those 05 minutes, **no new calls** will be **taken** nor recorded. The beacon simply refuses to log anyone new for 05 minutes (or whatever standardized time is created).

Now, those who hear the beacon **after** PY5CC **logs-in** will know that at 1411 UTC on March 28, 1992 PY5CC not only heard the beacon, but he also caused the beacon to hear him; at least for the next 05 minute (or other as standardized) time frame. After the **no-new-calls** time frame, the beacon continues to repeat the PY5CC example message until someone else (or PY5CC again) comes along and **reloads** the beacon memory; a new time, perhaps a new date, perhaps a new callsign. It might be a new callsign each 05 minutes in a long opening, or but one a month in times of poor propagation.

G) Each call, the date and time goes into a resident memory to be **cleared** (ideally by the local club or **beacon agent**) as often as the beacon memory requires clearing (ie. it is approaching capacity), or within a standardized time interval (ie. once per month).
Note: W3XO/5 suggests enlarging the project scope to include dumping the data 'upwards' to a UO-SAT category satellite on a scheduled basis for 'store and forward' downloading to a central collection point. He suggests this would allow placing SMART BEACONS in locales which are not easily reached nor routinely serviced. See later text.

This data is then forwarded to a group not unlike the RSGB committee formed by G2FKZ for the study of auroral propagation. It can remain in digital format until received by the collation and study group with suitable **dump** and **store** technology. It could even by forwarded via packet using HF bands or Oscar.

A possible word of caution that we not allow the data handling to become more important nor complex than the data itself. Our primary goal is to enhance 50 MHz activity by making DX contacts more frequent.

NOW we have a worldwide semi-automated propagation data gathering system. The data from each beacon is very easily analyzed for its own value and against all other beacons in the world in the same (general) time frame. Like the G2FKZ effort, the data simply flows in, begging analysis. From the worldwide data, profiles of propagation can be created for each hour of every day of the year against the number of beacons active. The information gathering might be augmented with hand written reports prepared by observers but it does not depend upon such reports (as in IGY or the G2FKZ RSGB program) to be a success.

AS A PRACTICAL TOOL:

Many amateur groups and publishers lament the 'change' in amateur radio over the past 30 years. We often self-criticize ourselves for **losing** our leadership role in everything from workbench technology (ie. amateur accomplishments in new technology) to operating skills. We worry incessently about our **ability to retain our worldwide frequency assignments** against commercial encroachment. Perhaps, **just perhaps**, we could be doing more with our skills, time-available and unselfish devotion to better justify our frequencies.

The 50 MHz band is recently (Cycle 22) **new** to many countries; especially in Europe. The assignment is not permanent **yet** in countries such as Germany, and is only marginally approved in others (ie. Switzerland).

The 50 MHz band is also our **only boundary propagation** assignment; where Es, F layer, aurora, various forms of backscatter and even EME are possible. **No other band offers such a variety of useable propagation forms** (see ZL0AAA six part series in July and August KA3B 50 MHz Newsletter; and New Zealand amateur publication BREAK-IN June-November 1991.) Many reading this paper with VHF interests should have no difficulty agreeing to these points.

This project begs international cooperation at the highest levels. It is my suggestions that the project seek the following:

1) IARU endorsement via ARRL;
2) JARL endorsement to support the IARU;
3) RSGB endorsement to support the IARU;
4) WIA (Australia) endorsement to support IARU;
5) NZART (New Zealand) endorsement to support IARU.

Although nothing directly requires the sanctioning of a WARC, the project itself if sanctioned by the IARU becomes an outstanding example of 'Amateur scientific efforts' (the use of our worldwide frequency assignments for the creation of new knowledge); the sort of project and effort which will help dull those attacks on amateur assignments in general at future WARCs. It is also possible that in countries where 50 MHz is **not presently allowed** that as a result of this project limited or total 50 MHz authorizations might follow (example: Zone 16-17-18-19 countries; Asia).

WHO BENEFITS?

Certainly basic science benefits; just as the G2FKZ publication RADIO AURORAS has swept away dozens of mysteries concerning auroral propagation, so too would the study and publication of the data from this project.

Certainly equipment suppliers benefit; increased interest in 50 MHz results in new rig/transverter/antenna sales. Publications benefit because new, some might even say **exciting** information sources open up.

Certainly amateurs benefit because of the enhanced activity on 50 MHz and the new worldwide dominion of the band created by the beacons and the fall-

out from the beacon operation. Assuming a central agent/agency/group (such as CSVHFS) coordinating the program, in the process of central data processing QSL cards for 'contacting' the various beacons would flow from the data files; ie. each contact is 'logged' by each Smart Beacon. For the average 50 MHz enthusiast, these QSL cards (providing proof of having contacted a [new] country on six meters) becomes the incentive that drives the program to success. The assumption is that such cards would be recognized for awards such as DXCC just as a two-way QSO confirmation card from say PY5CC is now accepted.

[AWARDS: I also envision 'Worked XX Beacons' awards, rightfully the domain of the study group formed to collect and study the data. The awards would be self-verifying since each beacon will report whom it 'logged in' and when.]

Certainly Amateur Radio benefits because of the importance of the work being conducted and the increased amateur esteem associated with the project.

The periphereal benefits are many. For example: if after two years of operation a beacon at ZD7 showed itself capable of being worked/heard in a particular part of the year at a distant region, this would provide excellent data as to when a DXpedition to ZD7 might best be scheduled in an ensuing year to make contacts. (Anyone who has packed 300 pounds of equipment traveling 2,000 miles to activate six meters at a distant point, and found the band flat inspite of best guesses, will appreciate this side-benefit!)

CYCLE 22

Solar cycle 22 is presently declining in intensity and is expected to meld into the beginnings of cycle 23 during 1995. There is evidence that E layer propagation is more frequent during periods of low (sunspot) activity.

The proposed SMART BEACON project has the opportunity to 'test' during the forthcoming solar minimum; a period of anticipated enhanced E layer activity. It is therefore suggested that a number such as 25 Smart Beacon units be created for test and field analysis over the period 1993-1997; a five year period. In such a test, the 'Phase One' Smart Beacons would be deployed in geographic regions representing rare countries on 50 MHz, but, within 2,500 miles of concentrated 50 MHz activity.

Note: 2,500 miles represents double-hop E layer propagation limits.

There are four primary centers of 50 MHz activity in the world:

a) Japan
b) Europe
c) North America
d) Australia-New Zealand

Within 2,500 miles of these activity centers are islands, radio 'countries' which are within transport access range of these centers. Prior to the peak years of cycle 23, such testing would allow the worth of the project to be scrutinized before Smart Beacons were deployed into truly remote-access places (ie. ZD7) with reduced opportunity to correct faults. As the worth of the project is proven, and as system bugs are eliminated, the scope of the geographic spread of the beacons and the number of beacons could grow parallel to the rise of cycle 23. By 1997, as cycle 23 matures the initial phase 1 units should be situated in areas closer to the geomagnetic equator to be operational in regions where the first improved F layer conditions are likely to be observed.

In the interim period (1993-1997) more than 100 totally new or at least rare countries would be activated within sporadic E range of these identified 50 MHz activity centres. Such opportunities to approach DXCC status could do much to keep 50 MHz interest high even during the solar minimum years.

Note: Addendum 'A' lists those countries where 50 MHz Smart Beacons might be deployed during 1993-1997.

NIT PICKING:

This paper has been prepared for consideration during the **1st Worldwide VHF Ionospheric Symposium**; a draft of this paper was prepared and circulated during mid-1991 to 15 active 50 MHz operators worldwide. Feedback from the original draft has been incorporated into this paper. Readers seeing this paper for the first time will benefit from a knowledge of the original considerations as well as the feedback, leading to this final paper. You may individually disagree with that reasoning, even after what follows, but at least you will know the detailed specifications were not plucked out of a vacuum.

1) **Beacon Siting:** A Grid Field contains 1/324th of the earth's surface. Australia overlays parts or all of 9 such fields; the continental 48 states 10 such fields. While it might be desireable to have more beacons than 'one-per-grid-field', as a practical matter this might not be possible. Here I have tried to balance **desireability** against practical constraints, at least for the original **100 beacon** units.
2) **50.010-50.090:** Possibly nobody will agree with this sub-assignment. As a practical matter, if you play with 100 beacon sites spread out over 100 grid fields, it quickly becomes apparent you could do all of this (with time and space diversity) in less than 30 KHz. A **QRM free** environment is not essential, but **it is desireable** as at the suggested power levels (+20 watts into a 0 dB gain omni antenna) the ERP is relatively low. I do not consider this matter critical and am sure the final outcome will be acceptable to most everyone.
3) **Conversion of existing beacons.** Nobody would be told nor pressured into eliminating existing beacons. It is envisioned that each of the present beacons falling where they could be integrated into the scheduled **siting plan** would be offered a **one for one replacement** of the existing system for a new, **standardized beacon.** If they say **no thank you,** well, we tried.
4) **Operational responsibility.** I believe it paramount that where possible a local amateur club be signed-on to oversee the operation of the beacon. First, in remote areas, this introduces new technology and a new amateur band to those responsible. During a June (1991) trip to the Azores my 50 MHz operation resulted in the local club becoming very interested. A new CU3URA 50 MHz beacon has been prepared for them to install and oversee. In a year or so, I expect to see CU3AA and CU3AK active on six meters. CU3URA, by the way, is the 'club call' for the Terceira ham group.
5) **Beacon format.** This will undoubtedly bring many comments. First my own shortcomings; I do not 'speak' **digital** (yet) and my own knowledge of costs-versus power needs-versus size-versus reliability is limited. For the beacon to be useful, it needs to **say** certain things; ie. **who** it is, **where** it is. For the project to reach its desired level of utility, the beacon also needs to:

A) Accept calls and 'log into memory' the date and time of the intercepting station.

B) Tell others (ie. those who hear the beacon after a station has **logged on**) who and when the **last prior** log-in occured.

I cannot answer from experience the size of memory possible (given the constraints listed above). Ideally, **every station** hearing the beacon who wishes to be **logged in** should be able to do so. But if we establish a once per month **data dump**, then working backwards there is a memory maximum which the storage can accomodate. If we assume a best case scenario where the maximum memory practical divided by X (the number of 05, or 30, or 60 minute time segments in a month) equals Y **log-ins**, then we have our **limits** established; allowing for 'percentage of time of band openings'.

This will be a design problem, not an operating problem. When the final design is **frozen** the interval between **new log-ins** possible will be self-evident. If that works out to a **05 minute hold** between new log-ins, I was a lucky guesser. If it works out to be something other than a 05 minute hold between log-ins, so be it.

(**Remember:** When each beacon is data-dumped, it will reveal a time sequential list of data showing the call sign, date and time of each log-in. This is the **base data** which will be studied by those collating the data.)

6) **System funding.** The average amateur, on a salary, retired or in business for himself has the usual personal budgetary constraints. Amateur groups such as JARL are no different; each of us must live within our means. As this is written, I have only the broadest concepts of the **total costs** involved here. Certainly they will be largely hardware oriented and as I am proposing the **100 beacons** be assembled by an amateur **group** as a project, costs reduce principally to parts.

My intuitive feeling is that finding the parts will not be a problem **if** the project in its final acceptable form has the support and backing of national and international amateur groups such as those cited. That does not necessarily mean I feel IARU (which always has no money) would pledge even a dollar to the project. Quite the contrary; there are enough direct, monetary beneficiaries and sufficient positive benefits to amateur radio and **Ham** operators overall to secure the funds needed **if** there is the tacit approval of the major **Amateur** organizations.

I suggest that we not **nit-pick** the unknown costs until we:

1) Know with some degree of accuracy the projected costs, and,
2) Know whether or not the project can earn the tacit support of key **Amateur** organizations.

Note One: N6CA and N4LTA, both designers/builders of 50 MHz beacons agree basic 20 watt output RF units with failure-proof designs and standard diode matrix keying should cost-out in the $35 region for parts in small quantities. K6MYC, provider of the omni-horizontal antenna for the CU3URA beacon suggests similar antennas could be created for less than $40 in materials. These are **not** numbers for Smart Beacons, but they do serve as a guide.

Note Two: K6FV, as relayed by N6AMG, offers that remote (island) beacons will be very difficult to site and maintain given the economic and technological levels of (typically) 'third-world' countries where sitings would take place. He worries that a fine piece of technological achievement may fail on site and

become a permanent non-operating fixture unretrievable and therefore of no value to the project. He further cites problems of a similar nature experienced with various beacons (ie. FO5DR) he has helped sponsor. N6AMG points at the 'many failed attempts' to site and keep operational non-smart beacons (ie. most recently 3D2FJ) in 'undeveloped' countries.

My response to both is that a standard format beacon has only limited value to the 50 MHz universe. A two-way capable Smart Beacon has the extra dividend of producing QSL cards to those who work it **and it is amazing how barriers evaporate when a QSL card for a new country is offered!**

Finally, OSCAR, a project of far greater magnitude, somehow always manages to scrape by. **If the project merits attention, the funds will be found.**

7) **Beacon (RF) Power:** N6AMG seriously questioned the selection of power output level (initially ten watts; here 20 watts) and 0 dB gain omni antennas. He and NI6E/KH6 properly question the value for backscatter and sidescatter of basically low-powered stations.

N6CA and N4LTA assure me that while solid state power levels of 50, 100 or even 150 watts are 'do-able' the system failures will increase as logarithmic function of power once we go beyond a de-rated 50 watt output transistor offering 20 watts nominal output.

N6CA also suggests RF shielding for the 'smart' portion will become far more critical at higher power levels and N4LTA (and others) point out the power needed versus power available equation. It turns out that a 40-(50) watt capable solar cell with marine battery is a practical power source for most locations with a 50% transmit duty cycle. Higher power creates demands for far more complex powering systems.

I would add that a 20 watt station operating 24 hours per day for a one year period may be infinitely superior to a 150 watt station operating one hour per day for the same year; or even an 800 watt station (such as W6JKV/portable wherever) operating 18 hours per day for five days. And during the initial 'Phase One' period where our primary propagation mode is E layer, a 20 watt station should prove very adequate if it is left in place and functions for 11 to 12 months before being moved to a new location.

AND?

The purpose of this paper has been to stimulate thoughtful discussion. IF it is true that working (new) (DXCC) countries is the number one motivation for serious interest in 50 MHz boundary propagation, this proposal merits your careful thought. As W3XO points out "The first hurdle is accepting the premise; after that it all becomes mechanical".

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For discussion, the following locations are proposed for Smart Beacon sitings during the period 1993-1997 (five years). Typically, a Smart Beacon would remain in one site for 11 months using the month of March to move, a low period worldwide for E layer propagation.

With 25 Smart Beacon packages and 80% operational at one one time, over five years there would be 100 countries covered by the end of 1997. Sites selected are within 2,500 miles of at least 20% of the region specified.

EUROPE:

4X	ZA	JX	7X	(44 total)
JY	LZ	TF	3V	
YK	UO	3A	5A	
OD	UB	TK	SO	
5B/ZC	UC	T7	5T	
TA	UP	HBO	TZ	
YI	UQ	HV	5U	
SV/A	UR	ISO	IT	
SV9	UA (Zone 16)	EA6	ST	
SV5	OHO	C3	ET	
SU	OY	EA9	D4	

JAPAN:

UA9 (Zones 18/19)	XU	(24 total)
KL7 (Aleutians)	HS	
BY	XZ	
BV	9M2	
HL	VU7	
JD1 (Ogasawara)	9M6	
JD1 (Minami-Tori-Shima)	9M8	
KH9	9V	
KHO	YB	
DU	KC6	
XV	XX	
XW	V8	

NORTH AMERICA:

V31	ZF	V4	J6	(35 total)
TG	6Y	VP2M	J8	
YS	KP1	VP2E	J3	
HR	KG4	FS	9Y	
YN	VP5	V2	8P	
TI	HH	FG	VP9	
HP	HI	YVO (Aves)	FP	
HKO (San Andreas)	VP2V	J7	OX	
HKO (Mapelo)	PJ5-8	FM		

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AUSTRALIA/NEW ZEALAND:

YB	A35	
VK9X	ZK2	
VK9Y	ZK3	
P29	FW	
H44	T2	
KC6	T30	
YJ	C21	
FK	5W	
VK9N	KH8	
VK2 (Lord Howe)	ZK1 (South)	
ZL7	ZK1 (North)	
ZL8	ZK3	
ZL9	T31	(26 total)

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15 others who participated in the maturing of this proposal.

AN OVERVIEW OF 50 MHz F LAYER PROPAGATION

for

Central States VHF Society - 26th Annual Conference

First Worldwide VHF Ionospheric Propagation Symposium

by

STEPHEN F. WAGNER

W7CI

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FIGURES **
(See Appendix A)

**Appendix A, which contains the figures for this paper, will be available at the conference for inclusion as an addendum.

WORLDWIDE VHF IONOSPHERIC PROPAGATION SYMPOSIUM

An Overview of 50 MHz Propagation

I. INTRODUCTION.

One of the most exciting experiences that the 50 MHz amateur will ever have is that of participating in a classic F2 band opening. It is especially exciting because of the relative rarety of it's ocurrence over the solar activity cycle. Actually there is little scientific and technical applications literature available for its use by those interested in the phenomenon of radio propagation at and near to the 50 MHz band.

This paper will present a current overview and the concepts that may be applied to the prediction, measurement and exploitation of F2 ionospheric phenomenon for the 50 MHz amateur.

II. COMMERCIAL AND MILITARY APPLICATION.

Little interest has been shown by commercial or military system users or implementers having an operational mission within the 30 thru 50 MHz spectrum for long haul communications. Those having interest are only concerned with essentialy line-of-sight/beyond-line-of-sight (LOS/BLOS) and meteor scatter propagation modes. Ionospheric propagation modes (eg, Sporatic E and F2) when they do occur on the communications channel are generally considered an interference nuisance.

As a result of a literature search, there are little direct scientific and technical applications literature available for reference by those interested in F layer ionospheric radio characteristics and conditions at ar near the 50 MHz band.

The use of the 30 thru 50 MHz spectrum for long haul ionospheric communication circuit links are not generally useful for classic High Frequency (HF) radio applications on 200 - 10,000 KM Sky-Wave radio paths. The commercial or military user requires a high link reliability and signal quality for satisfactory traffic throughput and a reasonable requirement for data error rate or voice inteligibility. The radio system engineer designs for specific requirements and criteria on an end-to-end (target) or an area of coverage (footprint) basis as desired and specified by the eventual system user.

We as VHF 50 MHz operators and F2 DX addicts have a different problem, we are interested in DX of oportunity on a world wide basis utilizing a variety of ionospheric propagation modes. High circuit reliability and signal quality are not the great concern for us as it is for the commercial or military user. The amateur is really only interested in DX of opportunity with signals adequate to pass a minimum of information for a valid contact or new grid, state, country or continent.

III. HISTORICAL OVERVIEW OF F2 OCCURANCES.

CYCLE 18 AND BEFORE.

The first reference to real F2 propagation phenomenon occuring on 50 MHz are the openings that were experienced shortly after WW II during the 1946 - 1948 period. Although there were unconfirmed reception reports dating from the mid 1920's no validated and confirmed contacts were made until the post WW II period. It must be also realized that we had no 6 meter band allocation prior to April 1946 and the pre war assignment was the 5 meter band (56 - 60 MHz). Any prior WW II F2 occurances were probably highly transient in nature because of lower solar activity, higher band frequency and state-of-art equipment of that time.

CYCLE 19.

The most spectacular occurance of F2 was during the solar cycle peak of 1957 thru 1959. The propagation of F2 was on a world wide and a daily basis especially during the equinox periods of these years.

CYCLE 20.

The next F2 cyclic peak ocurred during the mid to late 1960's with moderate propagation conditions. This peak was interesting from the standpoint of increased band activity and improved equipment such as almost 100% SSB used for non CW activity. The first confirmed 50 Mhz long path contacts were made during this cycle peak (a radio end-to-end path that is longer than the antipodes of the stations in contact).

CYCLES 21 AND 22.

The next two solar cycle peaks were almost as spectacular as the 1958/1959 peak in terms of openings and time of their duration. A number of long path openings were experienced by operators that no one thought possible before. This has been made possible by new knowledge of propagation modes, improved equipment, more available "real-time" information about the ionosphere, the availability of beacons, more population on-the-band and the ".885" liason network.

IN BETWEEN.

These events do not preclude the occurance of F2 during brief solar enhanced periods at cycle minimums and moderate activity periods.

FUTURE CYCLES ?

In terms of what the future solar peak will be, it may be too early to speculate. The statistical trend inferrs that we should not have had this last solar peak (cycle 22) at the level that was reached.It may be that the next solar activity peak (cycle 23) will be significantly lower than at any time in the last 50 years.

IV. THE SOLAR CYCLE.

The Solar Cycle consists of more than the commonly stated 11 year cycle of general solar activity. There are long and short time term trends that have a profound effect on 50 MHz propagation. Of note is the averaged 100 year modulation of the 11 year cyclic solar activity. This cyclic modulation trend is observed when evaluating past peak event solar cycle phenomenon. At the other end of the time scale, there are short term cyclic events that also have a great influence on 50 MHz propagation conditions. Of these are the rotation of the sun with respect to earth. The direct effect of flare, hole and coronal events sometimes repeat themselves each month, if they are still active. The occurances are the monthly cyclic events which cause geomagnetic field events, 10.7 cm flux variences (short term), absorption and high lattitude events (Aurora). Other detailed and associated events that may have direct influence on 50 MHz propagation that may be considered are the items depicted at Table I.

Any future predictions of solar cycle peak periods and when they may ocurr can only be based upon recognized and commonly based statistical analyitical theory and techniques. If it is assumed that on a cyclic basis; the solar cycle is time based upon an 11 year cycle, a gausian distribution can be applied to determine, within statistical limits, a probability that the next peak will be of at least an approxamate amplitude or peak in terms of an average sun spot number or flux value. As in any statistical inference, the population or number of historic events provide the necessary statistical base (the more population, the more accurate the data). Unfortunately, for this estimate the accuracy of the data prior to the last part of the 19TH century may be inaccurate because of non standard and state of the art methods of data collection. That may be one reason that <u>some</u> of the attempted predictions of the recent solar activity cycles were inaccurate.

Figure 1 shows the long term solar cycle history from 1755 to present. Figure 2 shows the geometry of a single smoothed solar cycle with primary propagation events denoted. What will cycle 23 be like?

V. THE SOLAR INFLUENCE MATRIX.

As we have stated, there are both long and short events and influences that fluctuate on a cyclic and on a single event basis and drasticaly effect 50 MHz propagation. Because of the highly transient and sporatic nature of F layer propagation at the higher spectrum a number of specific mechanisms are apparently at work.

Normally, it is assumed that the solar influences such as the 10.7 cm flux, plasma and geomagnetic events have direct impact to propagation at these spectrum regions, new evidence shows other specific phenomenon having combined effects that make F layer propagation additionaly transitory at 50 MHz.

The combined influencing factors that now must considered appear are those depicted at Table I.

TABLE I

MATRIX OF SOLAR INFLUENCES

GENERAL	SPECIFIC SHORT TERM
10.7 CM flux	Ultraviolet
SSAN	X-ray
Solar wind	magnetic particle Interplanetary
Plasmas	
Filaments	H-alpha calcium whitelite
Fields	
	Magnetic Green lines (5303A) Yellow lines (5694A) Helium line (10830A) Neutral line

VI. THE GEOGRAPHICAL INFLUENCE MATRIX.

If there are not enough propagation variability aspect caused by solar influences to the ionosphere, the geographical influences may be as complex in nature.

It is evident that no location on the earth exists with a constant geomagnetic field or flux density and that the actual solar flux intensity is not at a constant over a wide area (in contrast as if the propagating frequency was at 14 MHz) as it impinges upon the F layer.

This phenomenon accounts for the high variability of electron density necessary through and across the F layer refraction volume/zone and over its great circle path. There is now an apparent relationship of geographical latitude and longitude to the conditions favorable for useful F2 ionospheric refraction at these frequencies. Figure 2A shows a typical profile of electron and ion density for illustration of the ionosphere cross section.

Further considerations for the radio path and propagation geometry are the locations with respect to polar and equatorial regions and the path direction (eg, east/west, north/south). Full treatment of this subject is well beyond the scope of this paper and beyond the time alloted to this presentation.

TABLE II.

LOCATION	INFLUENCE FACTOR
Geographic Coordinate	Magnetic Flux and Field
STATION A	Polar Transit
to	Equatorial Transit
STATION B	Path Direction
	Absorbtion

VII. THE CONCEPT OF CIRCUIT RELIABILITY.

The common term used by those having a radio circuit definition and design requirement is to use the statistical term for reliability.

The objective in the design or utilization of a communication link or circuit is to generate and receive a signal strong enough to yield a useable signal-to-noise ratio for transfer of information of an acceptable quality. The acceptable signal-to-noise ratio is always dictated by the grade and type of service required; for example, near error free performance criteria for data transmission or intelligigibility of a voice transmission. Therefore, the circuit reliability can be defined as the fraction of time that an acceptable signal-to-noise ratio may be expected over the link or circuit for a stated period of time. The statement for what period of time must be defined when this statistic is used in reference. The referenced period of time may be during the 11 year solar cycle, on a monthly or daily basis or whatever relevent period of time is significant to the statement.

The distribution for reliability is assumed to be Gaussian and the values for the mean, standard deviation and lower decile points are used as constituent components for this criteria. Figure 3 shows the familiar Gaussian distribution curve for reference and presentation. In addition to its use as a criteria for radio links and circuits, this concept is used for all propagation prediction models.

VIII. FOOTPRINTS AND WINDOWS

The terms footprint and windows are commonly used for additional criteria in describing HF radio propagation phenomenon. A foot print is the area where the propaged wave arrives on the earth surface or designated target area. It may be further defined as an area profile having field strength bounds in volts/meter. The footprint will have bounds that are directly related to frequency, ionospheric density and geometry, number of multi-hops and geographic location. Figure 4 shows a typical one hop footprint in europe using highly directive antennas and a frequency near 50 MHz. Figure 5 shows a 50 MHz footprint across the southwest part of the US from a station located in ZL (ZL1ANJ).

A window is a general term used for historicaly optimum time for a radio path to open to a desired target area. The example shown at Table III is for South East Arizona (long. 110/16/36.6, lat. 31/32/4.75)(DM41UN). This table depicts the historical operating times for 50 MHz "long-haul" openings that have ocurred in the past 30 years. All data are shown for solar peak years with a 10.7 flux value of 155 to 380, a general statement of geomagnetic indices are shown and no circuit reliabilities for an 11 year cycle are assumed or considered.

TABLE III.

HISTORICAL 50 MHz PROPAGATION WINDOWS
(LONG. 110 - 16 -36.5/LAT. 31 - 32 - 4.75)

TIME (Z)	PATH (TO)	ACTIVITY
1500 - 1800	Europe (short path)	High Flux/Low Geomag.*
1700 - 1900	Europe (long path)	Very High Flux/Low Geomag. **
1600 - 2000	Africa (short path)	High Flux/Low-Mod. Geomag.
0300 (RARE)	Africa (long path) ZS,Z2	Very High Flux/Low Geomag.
1600 - 0100/0500	South America (short path)	High - Low Flux/Active Geomag.***
2100 - 0330	South Pacific (short path) KH6,ZL,KH3,FK,FO,etc.	High - Moderate Flux/ Low - Active Geomag.*
2200 - 0330	Pacific (short path) VK	High Flux/Low Geomag.
2300 - 0130	N. Pacific (short path) JA,HL,DU	High Flux/Low Geomag.
1430 - 1700	N. Pacific (long path) JA, ?	High Flux/Low - Mod. Geomag.
1530 - 2100	E.USA/CANADA (short path) W1-4,8/VE1-4	Very High - High Flux/ Low Geomag.
1900 - 0000	ALASKA/CANADA (short path) KL7,VE6/7,VY	Very High - High Flux/ Low Geomag.

NOTE:

* Includes probable Es enhancement/extention.
** Includes probable TE extensions on night side of path.
*** Includes Es extended TE and F.

IX. F2 PROPAGATION AT 50 MHz.

Generally the an F2 path or band opening can be described as being highly transitory with a very defined and small footprint at each end of the path. The path mid point (1 HOP) is usually associated with a high solar zenith. Most paths are near or above the frequency associated with the maxium useable frequency (MUF) that will allow the establishement of a useable signal-to-noise that will, for our purposes, pass the necessary information to make a valid contact.

The geometry of the propagation medium as it ocurrs within the ionosphere appears that the refractive mechanism is at a high hight, as high as 350 KM for most paths. It may be as low as 250 KM depending on the density of the F layer refraction medium volume. Simple trigonometric relationships show this for the 2000 to 3000 KM path lengths usually experienced during 1 HOP events. Experience has shown that this may occurr at frequencies as high as 70 MHz during periods of intense solar activity.

It is apparent that for openings having a sharply defined footprint that the dimention of the refractive medium is sporatic E like. It is a high ionic/electron density medium that is thin in depth and small in area. The refractive zone has low absorbtion properties at this frequency and at times is almost reflective in nature during periods of high ionization.

The area spread of the footprint is directly related to the volume and density of the refractive zone within the ionosphere and at its height. There is a direct relationship to this effect to the MUF that exists during the opening.

Multihop F2 openings require simultaneous events for sucess over given 50 MHz radio paths. This event occurs when the mid path is centered toward the zenith angle and enough ionospheric density is present along the path. There is a direct relationship to combination of the ionospheric volume and retention for multihop to occurr. The presence of multi hop F2 also appears to be related to the surface return of the propagating signal. Sea water is a good surface return medium and it appears that at these frequencies it is highly efficent. There is a direct relationship to the sea water roughness at these frequencies, the calmer the sea the better. Land surface returns are also related to conductivity and roughness of terrain. These effects can be related to the intensity of obliquely scattered return signals such as we see for "backscatter" effects.

There is evidence of other long haul mechanisms operating at 50 Mhz. It appears that an ionospheric duct extension may be responsible for many long haul path openings. This phenomenon seems to occurr over 10,000 KM plus paths with a MUF just at 50 MHz or slightly above it. Many of these type openings have no intermediate hops with no footprints at midpath points between the two stations having the opening. This type opening is somewhat common for the path between JA and south america.

A mechanism for the so called, "long-path" openings that have occured during Cycle 21 and 22, is an apparent multi mode extention of the radio path. This mechanism consists of the path being segmented and extended with a combination of F, TE and Es type propagation modes. This explains why various 50 MHz long path circuits can be extended through nightime and grey areas. These type paths usually have high absorbtion with the result being that signal levels are weak. It is obvious that this combined propagation mechanism is almost impossible to predict by current means. This mechanism is also present on shorter 50 MHz DX paths. A classic path extension of F2 to south america from the continental US is an extention by Es and is fairly common. A historical DX event occurred during early January 1992 where the europe to US F2 path was extended into the southwestern US.

Figure 6 depicts the generalized ray traces of these propagation mechanisms and phenomenon.

X. PROPAGATION PREDICTION AND SOUNDING.

The prediction of radio propagation conditions is based upon commonly accepted statistical theory and application. All models are designed using a general statistical distribution that is Gausian. The model must have limits for performance and must be based upon previous statstical events.

The predoment models and programs used for high frequency radio are those shown below;

* IONCAP (PC & Mainframe)
* MINIMUF (All Versions)
* PROPHET
* RAYTRACE
* ECAC
* IONSOUND

All these programs are used for HF predictions through the 2.0 - 30.00 MHz spectrum. They are fairly accurate up to the 18.0-20.00 MHz region. However, experience shows that all programs start to fail at frequencies above 20.0-25.0 MHz. The reason is that there are more complex physical influences starting to effect the model results. Of these influences not fully model exercised are those related to the treatment of the geomagnetic field and solar flux along the path to be evaluated. The field and flux effects along the given path are no longer an averaged wide area event that may typify the path at 10 MHz, they are now a widely varient event mechanism. Other fine grained solar events now appear to have an influence on the 50 MHz path and may further expand the matrix of variables required within the model.

Experience has shown that all the prediction models so far evaluated, are highly innacurate for use as a prediction tool for 50 MHz F propagation.

Figures 7 thru 10 show typical predicive data that may be obtained from these models and programs.

For today the best predictive methodology is "enlightened intuition" or predicting by "seat-of-the-pants". Operating experience over several solar cycles and minima probably is the best background that the 50 MHz DXer can have. In addition, the experienced 50 MHz DXer should have access to information that is available from a number of sources. These practical knowledge and information bases are as follows;

* WWV Solar information.
* Spot viewing.
* Other ITS bulletins.
* Participate in 28.885 MHz activity.
* History (Station Logs).
* 50 MHz beacons.
* Backscatter observation.

Although these are practical methods, they will never provide a unity or 100% prediction but their combination and knowledable application are not too bad for us in the 50 MHz DX world.

Ionospheric sounding techniques, although more applicable to those having the resources and need such as the commercial and military radio user, have some interest to us. Ionospheric sounding has real application to those having a need to probe the ionosphere on a real time basis. The most common real time sounding devices used in the commercial and military applications world are "Chirpsounders"; the Barry AN/TRQ-35 and AN/TRQ-42. These sounding devices are based upon point-to-point ionospheric oblique sounding. Figure 11 shows a typical "Chirpsounder" ionogram. Other sounders that are based upon oblique sounding are usually a pulse device that has some or intense interference potiential, the most intense being the old USSR (now CIS) OTH radar, the "woodpecker" whose secondary operational mission was radio sounding. Most sounding that has been done at high HF or low VHF used simple fixed frequency beacon transmitters and a receiver at the other end of the circuit that recorded received signal levels.

XI. CONCLUSION

There are a number of future actions that are within our capability that can be done to enhance the knowledge of radio propagation phenomenon at these high HF/low VHF spectrum frequencies. It is apparent that with more powerful processors and PC's that enhanced predictive models and algorythms can be developed. That may be the best challenge that a model developer can ever have. Below are some items that we may investigate to further capabilities for exploitation of the 50 MHz band in the future:

* Develop fine grained predictive models and algorythms that work above 20 MHz.

* Compile a world-wide operational data base for band opening history and phenomenon correlation/evaluation purposes.
(from station logs, etc.)

* Develop a world-wide coordinated network of 50 MHz automatic beacons.

* Find a readly available source of the fine grained short term solar data that is shown at Table I. Correlate and evaluate that solar data with band opening records.